ELEMENTS

OF

NATURAL PHILOSOPHY:

EMBRACING THE

GENERAL PRINCIPLES OF MECHANICS, HYDROSTATICS, HYDRAULICS, PNEUMATICS, ACOUSTICS, OPTICS, ELECTRICITY, GALVANISM, MAGNETISM, AND ASTRONOMY.

ILLUSTRATED BY SEVERAL HUNDRED ENGRAVINGS.

DESIGNED FOR THE

USE OF SCHOOLS AND ACADEMIES.

TWENTIETH EDITION.

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PREFACE.

The following work, designed for the use of schools and academies, embraces those portions of physical science usually presented in elementary works under the title of *Natural Philosophy*, including also a treatise on Astronomy. It does not pretend to be an entirely original work, though many of the illustrations and observations are the results of the author's own experiments, and so far as he is aware, are not to be found in any of the elementary books. The general plan of the work is that of *Blair's Philosophy*—a work which has been repeatedly published in this country, and afforded the matter for numerous other works purporting to be treatises on the same subject, without any acknowledgment of the sources from whence the compilers received their matter.

It has been the design of the author to preserve the *plan* of Mr. Blair, to omit such of his propositions as are antiquated, and to bring the work down to the present state of the science. In order to do this properly, it was necessary, not only to add much to the matter, but also to illustrate the different subjects with a greater variety of engravings; and in the latter particular, the author is happy to state, the publishers have spared no expense. From the length of time that many of the principles and propositions herein contained, have been known

it would be almost impossible to trace them to their proper sources; it is therefore deemed sufficient to say, that they have been collected from all the popular works on the subject, and put into such form as to be intelligible, and it is hoped interesting. to those for whom it was designed.

The treatise on Astronomy is mostly from Smith's edition of Blair, a treatise highly creditable to Mr. Smith, and one which it was found impracticable to present in a more concise form.* Some parts of it, however, were considered too scientific for the purposes for which it was designed, and accordingly, such portions have been removed, and their places supplied with other and more popular matter.

The merits of the present work are, that it contains a larger amount of matter in the same space than is found in most of the works designed for the same purpose. The principles and propositions being put in a large, and the illustrations and observations in a smaller type, tend to keep each department distinct, and thus prevent confusion in the mind of the learner. A great number and variety of illustrations have been added, and questions arranged at the bottom of the page, corresponding to the propositions: and while the language is sufficiently scientific for accuracy, the author trusts it is sufficiently plain and popular to be understood by all.

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* An arrangement was made with the owners of the copyright of Smith's edition of Blair, to make such use of it as the author deemed proper.

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2. Logs of wood floating in a pond of water approach each other, and afterward remain in contact.

3. The wreck of a ship, in a smooth sea after a storm, is often seen gathered into heaps.

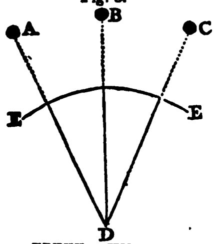
X. There are five kinds of attraction: Gravitation, Cohesion, Capillary, Electrical, and Chemical Attraction.

XI. The attraction of gravitation is that by which bodies, at sensible distances, tend to approach each other.

Illustration 1. Thus the moon draws up the waters of the ocean to form tides; the sun and earth are attracted towards each other; and a heavy body dropped from a height falls to the surface of the earth.

2. Every particle of matter in the universe is attracted to every other particle. In the solar system, all the planets gravitate towards the sun, and by his attraction are retained in their orbits in the same manner that a boy retains a stone in a sling while giving it a whirling motion, before he throws it at a distant object.

Fig. 3.



XII. By gravity, all terrestrial bodies tend towards the centre of the earth; and in all places equally distant from that point, the force of gravity must be equal.

Illustration. This may be illustrated by the accompanying diagram. E E being a portion of the earth's surface, and D its centre; the bodies A B & C, when allowed to drop, will fall in the direction of AD, BD, & CD.

XIII. The mutual attraction of any two bodies for each other is in proportion to the quantity of matter they contain

Illustration. If any body A attract another body B with a force of five pounds, a body weighing double that of A would attract B with a force of ten pounds. This law supposes the distance in each case to be the same.

XIV. The attraction of gravitation between any two bodies increases as the square of the distance decreases, and decreases as the square of the distance increases.

Illustration 1. Thus: if two bodies, placed 4 feet apart, be attracted with the force of 1 pound, at the distance of 2 feet the attraction will be 4 pounds, or the square* of 2, which is the distance.

* The square of any number is the product obtained by multiplying that number into itself. Thus: 2 multiplied into itself, or by itself, is 4; 4 multiplied by 4 is 16: hence, 4 is the square of 2, and 16 is the square of 4.

What is the second? What is the third? X. How many kinds of attraction are there? XI. Define the attraction of gravitation. What is the first illustration? What is the second? XII. What is the law of terrestrial bodies? Illustrate by the diagram. XIII. What is the law of attraction as to matter? How illustrated. XIV. What law as to distance? Give the first illustration.

2. If, on the contrary, the attraction at the distance of 2 feet be 27 pounds, at the distance of 6 feet the attraction will be only 3 pounds.

XV. The attraction of gravitation can be proved by experiment.

Observation 1. This first occurred to some French philosophers, who were sent out to make some experiments on point Chimborazo, in South America. These gentlemen observed, that a heavy weight attached to a long line and suspended from the perpendicular side of the mountain, was drawn from the perpendicular towards the mountain.

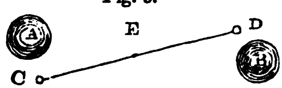
2. The phenomena observed by the French philosophers, gave rise to much discussion amongst men of science, in different countries; and it was thought desirable to settle the matter by an experiment, made expressly for the purpose: and, accordingly, George III. sent Dr. Maskelyne, the Astronomer Royal, to Scotland, in 1772, to make similar experiments on the north and south sides of Schehallien, a high and solid mountain in Perthshire. The plumb-line was found to deviate from the perpendicular, seven seconds, towards the side of the mountain, as seen in the wood-cut, Fig. 4.

Fig. 4.

3. This experiment proves the inferences of preceding observers, and the universality of the gravitating power.

4. The influence of general gravitation was also experimentally demonstrated in a different manner, by Mr. Henry Cavendish, in 1788.

Fig. 5.



Two small metallic balls, C and D, were fixed at the opposite ends of a very light deal rod, which was suspended horizontally, at its centre E, by a fine wire. This arm, after oscillating some time horizontally by the twisting and untwisting of the wire, came to rest in a certain position. Two great spherical masses, or globes of lead, A and B, were then brought into such a position, that the attraction of either globe would turn the rod C D on its centre E, in the same direction. By observing the extent of the space through which the end of the rod moved, and the times of the oscillations when the globes were withdrawn, the proportion was discovered between the effect of the elasticity of the wire, and the gravitation of the balls towards the leaden globes; and a medium of all the observations being taken, the experimentalist was enabled to ascertain not only the actual influence of gravitation on terrestrial bodies in general, but likewise its relative influence as depending on the density of the attracting body.

XVI. The force of gravity is less at the equator than it is at the poles, because the equatorial diameter is several

The second. XV. How was the attraction of gravitation proved by experiment? What were the phenomena observed by the French philosophers? What was the discussion, and what experiment to settle it followed? What did Maskelyne's experiment prove? Describe Mr. Cavendish's experiment. XVI. What is said of the force of gravity at the poles?

miles longer than the polar diameter, and because the swing, or centrifugal force of the earth at the equator diminishes the gravity.

Observation. Hence, a pendulum which, in the latitude of London, must be 39.14 inches in length in order to vibrate seconds, requires to be .13 inches shorter, or but 39.01 inches to perform its vibrations in the same time at the equator.

XVII. The force of gravity is greatest at the earth's surface, from whence it decreases upward and downward. It decreases upward as the square of the distance from the centre, and downward simply as the distance.

Observation 1. The power of gravitation is greatest at the surface of the earth, from whence it decreases both upward and downward; but not in the same proportion. The force of gravity *upward*, decreases as the *square of the distance* from the centre. This law was explained in Prop. XIV., but may be farther illustrated, thus:—Gravity, at the surface of the earth, which is about 4000 miles from the centre, is four times more powerful than it would be at double the distance, or 8000 miles from the centre. Gravity and weight may be taken, in particular circumstances, as synonymous terms. We say, a piece of lead weighs a pound or sixteen ounces, but if by any means it could be carried 4000 miles above the surface of the earth, it would weigh only 1-4 of a pound, or four ounces: and if it could be transported to 8000 miles above the earth, which is three times the distance from the centre that the surface is, it would weigh only 1-9th of a pound, or something less than two ounces.

2. It is demonstrated, that the force of gravity *downward* decreases, as the distance from the surface increases, so that at one half the distance from the surface to the centre, the same weight, already described, would weigh only 1-2 a pound, and so on.

Thus, a piece of metal, &c., weighing, on the surface of the earth, one pound, will,

At	The centre, weigh	0
	1000 miles from the centre, .	1-4 pound.
	2000 " "	1-2
	3000 " "	3-4
	4000 (at the surface,) . .	1

XVIII. Cohesion is the name of that attraction by which the particles of bodies are kept together. It acts upon the particles only while at insensible distances from each other, preserves the forms of bodies, and prevents them from falling to pieces.

Observation. It is highly probable, that what is called the attraction of cohesion and gravitation, may arise from one and the same cause; and could we examine bodies, and ascertain the relative distances of their atoms from each other, with the same facility as we can different bodies themselves,

XVII. How does gravity increase and decrease, from the surface of the earth? How is it illustrated? What is said of the force of gravity downward? XVIII. Define cohesion. What is the observation?

we should probably find the same law of attraction as in gravitation, namely, that it decreases as the square of the distance increases.

Illustration 1. The most familiar and simple method of illustrating cohesion, consists in preparing two flat surfaces of lead, as two leaden bullets, and if the surfaces, fresh and clean, be brought together with a twisting motion, they will adhere with a considerable force.

2. Two globules of mercury, being placed near each other, will run together and become one large drop—a union, which can arise only from their strong attraction. Drops of water will unite in the same manner.

3. Fresh-cut surfaces of Indian-rubber will unite in the same way; and, in consequence, we are enabled to apply this material to various useful purposes, such as air-tight tubes, by cutting off the edges of a thin strip of the rubber with a pair of scissors, and uniting the cut surfaces with a slight pressure.

4. Two pieces of perfectly smooth plate glass, or marble, laid upon each other, will adhere with considerable force, which will be much increased by moistening their surface with a little oil or water.

XIX. It is owing to the different degrees of cohesion in bodies, that some are hard, others soft; that some are in a solid, and others in a fluid state.

Illustration 1. It is by virtue of this attraction that solid bodies maintain their figure, and are prevented from falling to pieces by their own weight.

2. In all those bodies, called hard, strong, and brittle, the intensity of the cohesive force is very great; but the sphere of its influence seems to be very limited. Such bodies are incapable of being extended or stretched, in a perceptible degree, and require great force to break or tear them asunder—such is cast iron, certain stones, as the diamond, sapphire, &c.

3. In some bodies the cohesive force is weak, but the sphere of its action considerable. This property allows the particles to move slightly on each other, by the application of force; and when the force is withdrawn, the particles will return to their original position. Such is the case with all those bodies called elastic, as Indian-rubber, and all solids of a soft and viscid nature.

XX. If bodies be in the liquid form, the weight of their particles exceeds their mutual attraction; and if they be not confined, as by the bottoms and sides of vessels, they will be scattered by their own weight.

Observation. The particles of a solid body, placed in a vessel, have the same tendency, by reason of their weight; but their cohesive attraction predominating, prevents such an effect.

XXI. When the particles of a liquid are left to arrange themselves according to the laws of attraction, they assume a spherical shape.

What is the first illustration? What illustration with quicksilver? What illustration with Indian rubber? What with glass? What is said of the degrees of cohesion? What is the first illustration of the proposition? In bodies, hard, strong, and brittle, what is the cohesive force? How is cohesion in elastic bodies? XX. What is the cohesion in liquids? What is the observation? XXI. What effect have the laws of attraction on liquids?

Illustration. Thus, drops of water thrown on oiled silk or paper, and on the leaves of many vegetables, as the cabbage, will roll about, taking a globular form.. Water falling in drops from the eves of the house, and melted metal poured from a height, are instances of the same law. It is in this manner that leaden shot are made: the liquid metal is made to fall like rain, from a great elevation. In its descent, the drops become truly globular, and before they reach the end of their fall, they are hardened, by cooling, so that they retain their shape. It is, doubtless, owing to the same cohesive power, that the heavenly bodies have assumed the spherical form, a necessary result from an originally liquid state.

XXII. Cohesive attraction is remarkably exhibited between a solid and a liquid, as illustrated in the following instances :—

Illustration 1. A flat piece of glass, balanced at one end of a scale, and allowed to come in contact with the surface of water, will adhere to the liquid with considerable force.

2. In pouring water from a vessel, as a mug, it does not fall at once perpendicularly, but is inclined to run down the sides of the vessel, and especially if it be moistened, in consequence of its attraction between this and the liquid; and hence the difficulty in pouring from a vessel that has not a projecting lid.

3. The particles of water cohere so much among themselves, that delicate sewing needles, when carefully placed upon the liquid, will float; the weight of the needle not being sufficient to overcome the cohesion of the water. This illustration was formerly given as an instance of repulsion between the liquid and the solid.

4. On the same principle, some insects are comparatively so light, that they can walk on the surface of water without being wetted.

XXIII. It is chiefly owing to the different degrees of the attraction of cohesion in different liquids, that causes them to pour in different-sized drops.

Illustration. Sixty drops of water will fill the same measure as one hundred drops of laudanum, or one hundred and fifty drops of ether.

XXIV. Attraction exists between some liquids and solids, but not between others.

Illustration. Thus, quicksilver has no attraction for a glass rod; but if a strip of clean metal, as copper, silver, or gold, be plunged into that liquid, when it is withdrawn, it will be coated with the liquid.

XXV. When the attraction exists between a liquid and the interior of a solid, which is tubular or porous, it is called *capillary* attraction.

Illustration 1. Instances of this are innumerable. Liquids are thus draw

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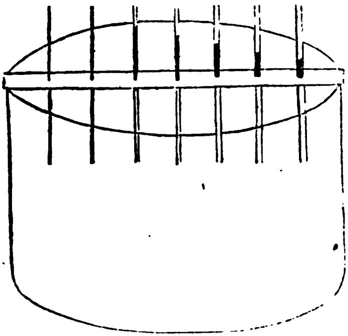
Give the illustration of this law. XXII. What remark of solids and liquids, as to attraction? Give the first illustration. What is said of pouring water from a mug? What remark illustrated by a sewing needle, and what was the former explanation? What remarks on insects? XXIII. What is the remark on the relative size of the drops of liquids? What is the illustration? XXIV. What is the 24th proposition, and how is it illustrated? XXV. Define capillary attraction. What is the first illustration?

into the pores of sponge, sugar, lamp-wick, &c. Water put into the saucer of a flower-pot, is drawn up by capillary attraction, into the earth contained in the vessel.

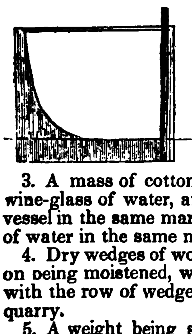
Fig. 6.



2. When an open glass tube is partly immersed in water, the liquid within the tube rests at a higher level than that on the outside; and the difference of level is greater the smaller the bore of the tube.

Experiment 1. Take a number of small glass tubes, of different-sized bore, and passing them through a thin strip of wood, place it across a tumbler of coloured water, allowing all the tubes to be immersed, as seen in the wood cut, the liquid will rise to different heights in the several tubes, but the highest in the tubes having the smallest bore, because the attraction is in proportion to the quantity of surface exposed; and the small bore affords comparatively more surface than the large.

Fig. 7.



2. Take two pieces of glass, five or six inches square, join any two of their sides, and separate the opposite sides with a small piece of stick, so that the surface may form a small angle; then immerse them about an inch deep in a basin of coloured water, and the water will rise between the glasses and form a beautiful curve, called a *hyperbola*. See the wood-cut.

3. A mass of cotton lamp-wick, or thread, with one end plunged into a wine-glass of water, and the other hanging over the edge, will empty the vessel in the same manner as a syphon would. A towel will empty a basin of water in the same manner.

4. Dry wedges of wood, driven into a groove formed round a pillar of stone, on being moistened, will so expand as to force the rock asunder in a line with the row of wedges. In this way mill-stones are often split out from the quarry.

5. A weight being suspended by a dry rope, will be drawn upward with great force, by simply moistening the rope with water. The moisture imbibed by capillary attraction, into the substance of the rope, causes it to be shorter.

At one time, it was considered that the sap of trees ascended from the roots by capillary attraction; but it is now considered an action peculiar to vegetable life.

XXVI. Electrical attraction, is that which is exhibited

What is the second? What is the first experiment? What is the second experiment? What is the third? Fourth? Fifth? What is said of capillary attraction in a rope, and what of the ascent of sap in trees? XXVI. Define electrical attraction.

on rubbing a dry glass tube with a dry silk handkerchief, by which the tube becomes capable of attracting light bodies, such as small pieces of down, paper, &c.

Observation. Magnetic attraction, by which power the loadstone attracts and lifts fragments of iron or steel, is now considered only a modification of electrical attraction, and will be treated of under that subject.

XXVII. *Chemical attraction*, or *affinity*, is that which unites the particles of two or more distinct substances to form one compound.

Illustration. Thus we combine zinc and copper to form brass; oil of vitriol and lime, to form plaster of Paris; and oil of vitriol and iron rust, to form copperas.

Observation. There are about fifty-three or fifty-four substances in nature, which, in the present state of science, are recognised as distinct from each other, and are here denominated different kinds of matter. Thus, metallic tin and silver resemble each other in appearance, but, chemically considered, they differ as widely as quicksilver and water; while the diamond and pure charcoal, substances so perfectly unalike in appearance, are chemically one and the same.

PARTICULAR PROPERTIES OF BODIES.

Observation. Having described most of the properties common to all bodies, together with a few modifications which seem somewhat peculiar, as magnetic and electrical attraction; we have now to notice a few properties which, though possessed in a measure by most bodies, predominate in some, and almost or entirely disappear in others, such are—

XXVIII. Porosity, density, hardness, elasticity, brittleness, malleability, ductility, pliability, and tenacity.

Observation. It is well known that all bodies, when heated, expand or become larger, and, in cooling, contract or become smaller; hence, the particles of which bodies are composed, are forced farther asunder in the first instance, and brought nearer together in the second. If, therefore, we can reduce the temperature of any body, however low it may be at the time, the body will contract—thereby proving that the particles were not originally in contact. If we continue to reduce the temperature, the bulk will diminish in the same proportion; and hence we conclude, that the particles of bodies are never in contact, and consequently all bodies are, more or less, porous.

XXIX. DENSITY is a term used to express the relative quantity of particles in a given space; and POROSITY, the distances of those particles from each other.

What is said of magnetic attraction? XXVII. Define chemical attraction. Give the illustration. What is the observation on the varieties of matter? What is the observation on particular properties of bodies? XXVIII. What are the particular properties of bodies? What is the observation on expansion and contraction? XXIX. Define density and porosity.

XXX. Density is very different in different bodies.

Illustration. A cubic inch of lead is 40 times heavier than the same bulk of cork; and quicksilver 14 times heavier than an equal bulk of water.

XXXI. The density of bodies depends on two circumstances: 1st. The size or weight of the particles. 2d. On the distances of the particles from each other.

Illustration. Lead is heavier than the same bulk of iron, and lighter than that of gold. Hence, it is supposed, that the particles are heavier in the gold and lighter in the iron.

XXXII. Since the particles of bodies can be brought nearer together by cold, and the same is also true of pressure, they are never in actual contact; therefore, all bodies are porous.

Observation. In some cases, the pores are visible to the naked eye; and in many more, they become so by means of the microscope; and, in all cases, they can be proved to exist by some means.

Illustration 1. When water freezes, the crystalline needles, or plates of ice, cross each other, and thus form small vacant spaces or pores.

2. Bone is nothing but a tissue or network of bony matter, as little solid as a heap of packing-boxes. The pores are generally filled with oily matter.

3. Wood is a congeries of parallel tubes, like bundles of organ-pipes.

XXXIII. *Hardness* is the resistance which bodies make to mechanical division. It is generally measured by the circumstance, that one body will scratch another.

Observation. Hardness is not always in proportion to the density.

Illustration 1. Gold, though soft, is 4 times heavier than diamond, and quicksilver twice as heavy as the hardest steel.

2. Diamond is the hardest of all known substances, and can be polished only by its own dust.

3. It is remarkable that steel can be made, by heating and slow cooling, as soft as pure iron; or, by sudden cooling, as hard as glass. This was one of the most important discoveries in the arts; for it has given to man the art of making edged tools, instruments by which he moulds all other substances to suit his wants. Thus, a savage will, for twelve months, with fire and sharp stones, fell a tree and form it into a canoe; and a modern carpenter, with his tools, will do the same work in a day or two.

XXXIV. *Elasticity* is the property of yielding to force, and returning to the original state when the force is removed.

Illustration 1. Indian-rubber is one of the best examples of this property—

XXX. What is the illustration of density? XXXI. On what does the density of bodies depend? How is it illustrated? XXXII. How is porosity proved? What observation is made on this subject? What is the first, second and third illustrations? XXXIII. Define hardness. What is the observation? What is the first illustration? The second? The third? XXXIV. Define elasticity. Give the first illustration.

The mineral called isinglass, or mica. A ball of ivory, dropped upon a pavement, will rebound high in the air from its elasticity.

2. A good steel sword, may be bent till its ends meet; yet, when allowed, it will return to perfect straightness: while a rod of bad metal will be broken, or permanently bent.

3. Putty, dough, and paste, and all liquids, are among the inelastic bodies; while air, and all aerial substances, are the most elastic of all bodies with which we are acquainted.

XXXV. *Brittleness* is a property by which bodies are easily broken into fragments, and belongs, generally, to hard bodies.

Illustration. Glass, sulphur, sealing-wax, and rosin, are familiar instances of brittle bodies.

XXXVI. *Malleability* is the property of being hammered, or rolled, into thin leaves or plates.

Illustration. Thus gold, one of the most malleable substances in nature, is hammered into exceedingly thin leaves; tin, into leaves called tinfoil; and iron, thin plates, called sheet-iron.

XXXVII. *Ductility* is the property of being drawn into wire.

Illustration. Platinum is the most ductile of all the metals; silver, the next; and iron, the third.

XXXVIII. *Tenacity* is the force with which the particles of bodies cohere, and is generally expressed by the term *toughness*.

Illustration. Tenacity is generally ascertained by the weight required to separate a given-sized wire, or cylinder, of the substance, whatever it be. Thus an iron wire, of one inch in diameter, will support a weight of 26 tuns, while a similar wire of lead, would support only 5 1-2 tuns.

XXXIX. *Pliability* belongs to those bodies which allow considerable motion of the particles on each other, without breaking.

Illustration. Such are tanned leather, in contradistinction to raw hides; unglazed linen, in contradistinction to glazed; sized and unsized paper.

XL. *Motion* is the continued and successive change of place of any body. It is absolutely impossible either to produce or to destroy any thing without it; consequently, every thing that happens depends upon motion. By force, we mean that which produces motion.

Give the second and third illustrations. XXXV. Define brittleness. What is its illustration? XXXVI. Define malleability, and give the illustration. XXXVII. What is ductility, and how is it illustrated? XXXVIII. What is tenacity? How is it ascertained? By what is it illustrated? XXXIX. Define and illustrate pliability. XL. What is motion? What is force?

XLI. Motion is *absolute* and *relative*. *Absolute* motion is where the motion is considered without regard to any other body, and can be conceived by supposing an unbounded space, and a body moving through it. *Relative*, is where the motion is considered in relation to some other body, which is either in motion or at rest.

XLII. The general laws of motion, which have been deduced from innumerable experiments and observations, are :—

1. That *every body will continue in its state of rest, or of uniform motion in a straight line, until it is compelled, by some force impressed, to change its state.*

2. That *the change of motion produced in any body, is proportioned to the force impressed, and is always made according to the direction in which that force acts;* and,

3. That *action and reaction are always equal and contrary to each other.* Or, *the mutual actions of bodies upon each other, are equal and in contrary directions, and are always to be estimated in the same straight line*

Fig. 8.

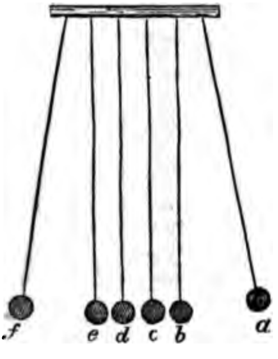


Illustration. The principle of action and reaction is illustrated by a number of ivory balls suspended by small cords as in the woodcut. If now one of the exterior balls as *f* be drawn apart from the rest, say two inches, and then be allowed to fall against *e*, *e d c b* will remain quiet, while *a* will fly off two inches from *b*, or just as far as *f* was drawn apart from *e*; because the impulse or action of *f* by means of the elasticity of the ivory balls is transmitted through *e d c b* and reacts on *a*.

It is on this principle that a sky-rocket ascends; the large quantity of gaseous matter which is constantly forming at the lower part by expanding, presses on

XLI. How is it divided? XLII. What are the general laws? What is the experiment, and what other illustration?

the air below, and on the rocket above, by which force it is impelled upwards.

Observation. The third law shows the utter folly of all attempts at procuring perpetual motion by self-moving machinery; for, inasmuch as matter at rest resists motion, a constant renewal of the power is required to continue motion.

XLIII. In estimation of motion, we consider the following circumstances:—

1. The *force* which produces the motion.
2. The *quantity of matter* in the moving body.
3. The *velocity* and direction of the motion.
4. The *space* passed over by the moving body.
5. The *time* employed.
6. The momentum, or force, with which it strikes another body opposed to it.

XLIV. The momentum or quantity of motion, in a moving body, is estimated by the velocity multiplied by the weight.

Illustration 1. If the same force impel two balls, one of a pound weight and the other of two pounds, it follows, that since the balls can neither give force to themselves, nor resist that impressed upon them, they will move with the same momentum, but the lighter ball will move with twice the velocity of the heavier one, because the resistance is only half as great.

2. If a cannon ball were forty times the weight of a musket-ball, but the musket ball moved with forty times the velocity of the cannon-ball, each would strike any obstacle with the same force, and overcome the same resistance; for the one would acquire as much force from its velocity as the other does from its weight.

3. A very small velocity may be attended with enormous force, if the mass moved be proportionably great. A large ship, floating near a pier-wall, may approach it with a velocity so small as scarcely to be perceived, and yet the momentum may be so great as to crush a small boat.

4. A grain of sand, or of shot, flung from the hand, and striking the person, will occasion no pain, and may even scarcely be felt, while a block of stone, moving with the same velocity, would occasion death.

5. When two bodies, moving in opposite directions, meet, each body sustains as great a shock as if being at rest it had been struck by the other with the united force of both. Thus, if two equal balls, moving at the rate of ten feet per second, meet, each will be struck with the same force as if, being at rest, the other had moved against it at the rate of twenty feet per second. It is on this account that, when two persons, walking in opposite directions, meet, they suffer a more violent shock than might be expected;

What is the substance of the observation? XLIII. What are the circumstances considered in estimating motion? XLIV. Define momentum, and how it is estimated. What is the illustration by two balls? What is that by a cannon and a musket ball? What is the illustration by the ship? What is the illustration by a grain of sand or shot? What illustration by the meeting of bodies, and how is the subject farther illustrated?

...ce the devastation and ruin from the meeting of two ships, steamboats, ...railroad-cars, moving in opposite directions.

XLV. The velocity of motion is estimated by the time employed in moving over a certain space, or by the space passed over in a certain time. The less the time, and the greater the space moved over in that time, the greater is the velocity.

Illustration 1. *To ascertain the degree of velocity,* the space run over must be divided by the time.

2. *To measure the space run over, the velocity must be multiplied by the time;* for it is evident, that if either the velocity or the time be increased, the space run over will likewise be increased.

3. If the velocity be doubled, then the body will move over twice the space in the same time; if the time be twice as great, then the space will be doubled; but if the velocity and time be both doubled, then will the space be four times as great.

Example 1. If a ship sails at the rate of 12 miles in an hour, or sixty minutes, then the velocity is equal to one mile in five minutes.

2. If two persons set out together on a journey, and one walks two miles and a half, and the other walks five miles an hour, the velocity of the latter will be double that of the former.

XLVI. A body acted on by a single force, moves in a straight line, and in the direction of the force.

Illustration 1. A ball, floating in water, is driven northward, by a wind blowing in that direction.

2. A body, dropped from a height, falls in a direct line towards the centre of the earth, because the moving force is in that line.

XLVII. A body, acted on by two forces at the same time, and in different directions, as it cannot obey both, it takes a middle course between the two. This result is called the *Composition of Forces.*

Fig. 9.

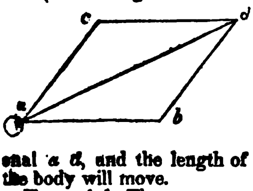


Illustration. Suppose a body *a* to be acted upon by another body in the direction *a b*, while, at the same time, it is impelled in the direction *a c*, then it will move in the direction *a d*. If the lines *a b* and *a c*, be made in proportion to the forces, and the lines *c d*, and *d b*, be drawn parallel to them, so as to complete the parallelogram, then the line which the body *a* will describe, will be in the diagonal *a d*, and the length of this line will represent the force with which the body will move.

Example 1. There are many instances in nature, of motion produced by

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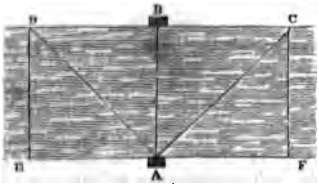
XLV. How is velocity of motion estimated? Give the first illustration. Second. Third. What is the first example? What the second? XLVI. What is said of bodies acted on by one force? Give the first illustration. Second. XLVII. What is said of bodies acted on by two forces? Illustrate a body acted on by two forces, in different directions.

several powers acting at the same time. A ship driven by the wind and tide is one; so also is a paper kite, acted upon by the wind in one direction, and by the string in another.

2. A ball fired from a cannon is acted upon by two forces, the one is that occasioned by the powder, the other is the force of gravity.

Fig. 10.



3. Thus, a ferry-boat, in crossing a river from A to B, where there is a strong current from A to E, would be carried in the line A D, and land at D; and, in order to gain the shore directly opposite, as at B, must necessarily direct the boat up the stream, far above the proposed landing-place, as towards C, which will be the medium between A E and A B.

XLVIII. A curvilinear motion is produced by constantly changing the direction of the moving force · under this head is included the law of *projectiles*.

Definition. Projectiles are bodies thrown in the atmosphere in a perpendicular, oblique, or horizontal direction; and the paths they describe have a curvilinear form, called the *parabola.*

Fig. 11.

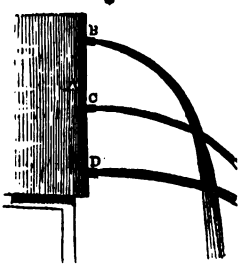


Illustration 1. An oblique or horizontal jet of water, is an instance of the curve, described by a body thus projected. The particles of the liquid move in the line that each would do if projected singly; and the continued succession of them, marks the line through which each passes before it falls. See letters B, C, D in the wood-cut.

2. A cannon, or musket-ball, shot horizontally, over a level plain, will touch the ground, or plain, just as soon as another ball dropped directly from the cannon's mouth; for the forward, or projectile force, does not at all interfere with the action of gravity. This fact, which people, without reflecting, are disposed to doubt, proves, in a striking manner, the immense velocity of a cannon-ball, which will, perhaps, move six hundred feet before touching, during the half second that a ball dropped from the hand reached the ground, only four feet beneath it. This fact also shows the reason that, when we wish to throw a ball to a great distance, we should elevate the gun.

Illustrate by the cannon-ball. Illustrate by a ferry-boat. XLVIII. What is curvilinear motion? What are projectiles and their paths? What is the first illustration of the curvilinear motion? What is the second?

3. This principle is further illustrated in the woodcut below, fig. 12, where the parabolic line *c d* represents the course and distance that the ball takes when fired from the cannon, and the perpendicular line *c, d,* the distance and direction when dropped from the height, both reaching the point of destination at the same time.

Fig. 12.

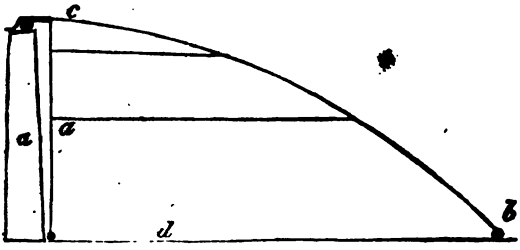
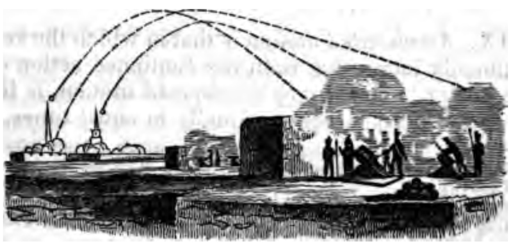


Fig. 13.



The above woodcut fig. 13, represents a bombardment, and the three lines indicate the curves made by the balls.

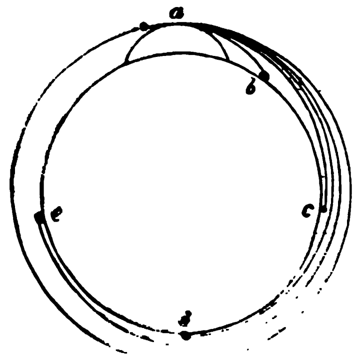
4. If the bombardment had been conducted from an elevation, instead of the level surface, the balls would have gone beyond the city as shown by the familiar fact, that we can throw a heavy body to a greater distance from an elevation, as the steep bank of a river, than on a plain or level ground.

It is on this principle that Napoleon bombarded Cadiz, at the distance of five miles and from a greater elevation the balls could have been thrown to a still greater distance.

Suppose the circle *a b c d*, (fig. 14, p. 26,) represent the surface of the earth, and *a* be a high mountain extending above the atmosphere. A ball fired

What experiment is mentioned to illustrate the subject? What illustration is given from an elevation, and what remark of Bonaparte? What is the illustration from the figure?

Fig. 14.



horizontally from this height might be projected with a given velocity forty or fifty miles to *b*, with increased velocity, it would reach *c*, and with a little more it would reach *d*, and more still, it would be carried to *e*. If it could be projected with about ten times the velocity of a cannon-shot, it would have followed the exterior line, until it reached the original point of departure, and its velocity being undiminished it would continue to repeat its revolutions around the earth in the same manner as the moon now does.

It is owing to the exact balances of gravitation on the one hand, and the projectile force on the other, that the heavenly bodies are retained in their orbits.

XLIX. *Accelerated* motion is that in which the velocity is continually increasing from the continued action of the motive power. *Uniformly accelerated* motion, is that in which the velocity increases equally in equal times.

Illustration 1. The increasing velocity with which a body falls to the earth, is an instance of accelerated motion, which is caused by the constant action of gravity.

2. A cannon-ball is acted on by a single impulse of the powder, and the accelerating force of gravity; it therefore describes a curve. This is the foundation of the art of gunnery.

Observation. Were falling bodies moved only by one impulse from attraction, the power of gravity not continuing to act on them during their descent, they would fall, from whatever height, with the same equable or uniform motion through their whole course, passing through equal spaces in equal times; but falling bodies do not move in this manner; they fall with *accelerated*, that is, *continually-increased* velocities. The truth of this statement is evinced on watching the fall of an apple from a high branch of a tree. Its form and colour may be seen when it begins to fall, but when near the ground, the motion has so much increased that neither form nor colour, but only the shadowy outline of the body, can be seen.

L. A new impression being made upon a falling body, every instant, by the continued action of gravitation,

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... Is this motion identified with? XLIX. What is said of accelerated motion? first illustration: the second; and the observation. L. How is explained increased velocity?

while the former impulse still remains, the velocity must continually increase.

LI. The velocities of falling bodies, are in proportion to the spaces run over and the spaces passed over in each instant, increase as the odd numbers 1, 3, 5, 7, 9, &c.

Fig. 15.

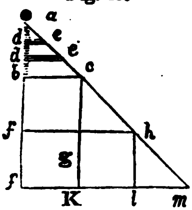


Illustration 1. The space described by a body falling from *a*, fig. 15, in the time expressed by *a b*, with a uniformly accelerated velocity, represented by the lines *d e*, on which the last degree is expressed by *b c*, will be represented by the area of the triangle *a b c*. If gravity ceased to act, the space passed over in the next portion of time, *b f*, would be measured by *b f*, multiplied into the velocity of *b c*, that is, by the rectangle *b c g f*, which is equal to twice the triangle, *a b c*. But if gravity still acts, then the triangle *c g h* must be added; of course, the body moves over three times the space in the second instant that it did in the first. The next portion of time it would move over five times the space represented by the two rectangles and triangle; and in the fourth portion of time, seven times; and so on in arithmetical progression.

It follows, that the *whole* space described, is as the square of the time; that is, in twice the time it will fall through four times the space; in thrice the time, nine times the space, &c.

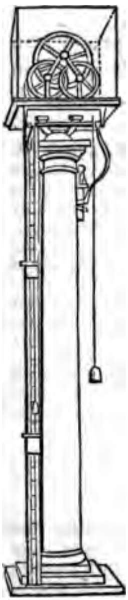
2. It has been ascertained, that this fall of bodies is about 16 feet the first second of time; three times 16, or 48 feet, the next second; five times 16, or 80 feet, in the third second; seven times 16, or 112 feet, in the fourth second; and so on, following the odd numbers, 9, 11, 13, 15, 17, &c. It will follow, that an apple, falling from the top of a tower or steeple, and reaching the ground in 4 seconds, will give the height 256 feet; a method by which such heights, as well as the depth of deep pits, may be easily measured by multiplying the time occupied in falling through the whole distance by itself, and that again by 16, the number of feet fallen through the first second.

3. Thus, suppose the time	4 seconds,
multiply it by itself, that is	4
then this product, ...	16
is to be multiplied by	16
	96
	16
the number of feet passed in a second, and . . .	256

the product, is the number of feet passed through in 4 seconds.

LI. What is the proportion of velocity in falling bodies? Give the first illustration. The second. What is the third illustration?

Fig. 16.



4. A very ingenious instrument for measuring the increase of falling motion, was contrived by Mr. Attwood. It consists of a wooden column, not less than ten feet high, with a rod marked by feet and inches, and two weights suspended over easily-turned pulleys. The rapidity of the falling motion in the heavier of the weights is retarded by the lighter weight, while the gradual increase is scarcely influenced, and may be seen by the eye as it descends along the rod, while the time may be noted by listening to the beats of a clock. Annexed is a figure of the instrument.

5. The great additional force with which a falling body strikes the ground, in proportion to the height it falls from, may be easily understood from these illustrations. It is on this principle that the machine for driving piles is constructed, a heavy weight being drawn up high and let go, when it comes down on the head of the pile with great force. Even hailstones, small and comparatively light as they usually are, often do much damage from the same increase of their motion and force in falling. The account given in the Alcoran of the destruction of Sodom is, that on each hailstone rained from heaven was written the name of the individual it was destined to kill, and that it penetrated the body from the head to the heel—a Mohammedan legend, of course—but not founded, like some of them, on physical impossibility.

6. It is the same principle which renders it more dangerous to leap from a high wall than from a low bank; and which makes a small stone, when rolled down a hill, often productive of serious injury. It is this also which produces the tremendous sweep of an Alpine avalanche, "like the awful rushing of one which I witnessed," says Rennie, "in 1832, at the source of the Arveron, in the valley of Chamouni."

7. On falling liquids, the principle acts in conformity to their slightest cohesion, the lower portions falling faster than the upper, and consequently diminishing the bulk of the stream in proportion to its swifter descent. A stream of honey, thus let fall from a height, may be observed to taper off towards the lower end; and a waterfall becomes thinner and broader as it descends, as is obvious in such larger bodies of water, as Cora Linn on the Clyde, and the falls of the Rhine, of the Catskill, &c.

8. The same principle is illustrated on a vast scale at the falls of Niagara; where the broad river is seen, first bending over the precipice, a deep slow moving mass; then, becoming a thinner and thinner sheet, as it descends, until at last, surrounded by its foam and mist, it flashes into the deep below, almost with the velocity of lightning.

LII. All motions produced upon a body, by one force only, must be made in a right line. Therefore, a body

What is the principle of Attwood's machine? What is said of the pile-driving machine? What of hailstones? What illustration by leaping walls, rolling stones, and avalanches? What of falling liquids? What of the falls of Niagara?

moving in a curvilinear direction, must be acted upon by two forces at least; and when one of these ceases to act, the body will move again in a straight line.

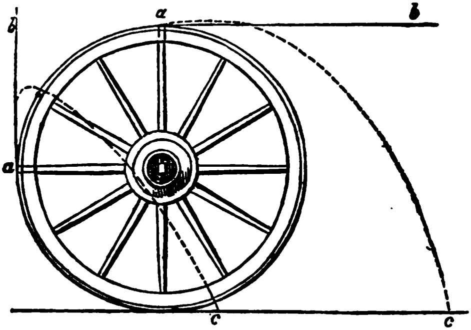
Illustration. A stone in a sling is moved round by the hand, while it is pulled towards the centre of the circle which it describes by the string. But when the string is let loose, the stone flies off in a line as straight as if shot from a gun.

LIII. The force required to keep the body in a circular motion, is called the *Centripetal*, or centre-seeking force. That which tends to move outward, or from the centre, is called the *Centrifugal*, or centre-flying force.

Illustration 1. Thus, a sling-cord is always tight, while the stone is whirling, by the centrifugal force; and while the cord is strong enough to support the stone, it pulls it towards the centre, and thus becomes a *centripetal*, while the weight of the stone is the *centrifugal force*.

2. The motion of mud flying from the rim of a coach-wheel, in rapid motion, is a striking illustration of centrifugal force, as seen in the accompanying wood-cut.

Fig. 17.



Coach-wheel throwing off mud; *a* the point at which the mud flies off; *a b*, the straight line in which it would move but for the central force which compels it to follow the parabolic curve, *a c*.

3. Bodies laid on a table, which is caused to whirl like a horizontal wheel, are quickly thrown off by the centrifugal force.

4. A wet mop, or battle-brush, made to turn quickly on its handle as an axis, throws off the water in all directions, and soon dries itself.

5. A tumbler of water, placed in a sling, may be made to vibrate like a

What illustration by a coach-wheel? What by a table? What by a wet mop? What by a tumbler of water?

pendulum, by gradually increasing the oscillation, until, at last, the vessel may be completely inverted without spilling the water.

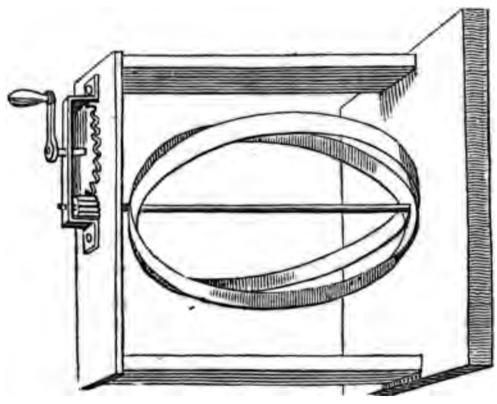
6. On the same principle, namely, centrifugal force, put some water in a common water-pail, suspend it by a string, and set it in a whirling motion, the liquid will rise up on the sides of the pail, giving a concave or hollow surface to the whole liquid within.

7. Carriages are often overturned by quickly rounding corners. The inertia carries the body of the vehicle forward in the same line of direction, while the wheels are suddenly pulled around by the horses into a new one. Thus, a loaded stage running south, and suddenly turned to the east, strews the passengers on the south side of the road.

8. A ball of soft clay, with a spindle forced through its centre, if made to turn quickly, soon ceases to be a perfect ball. It bulges out in the middle, where the centrifugal force is, and becomes flattened towards the ends, or where the splindle issues.

9. The centrifugal force acting upon the form of our earth, in its daily rotation has caused it to bulge out about seventeen miles at the equator, and to be flattened at the poles in the same proportion; a mass of lead that would weigh 1000 pounds at the poles, weighs five pounds less at the equator, in consequence of the centrifugal force. An apparatus for illustrating the centre-flying force consists of two circular elastic hoops, on an axis moved by a crank and wheel. When put into rapid motion the hoops are observed to bulge out at the middle, in consequence, of the centre-flying force. See accompanying wood-cut.

Fig. 18.



10. If the rotation of our earth were seventeen times faster than it is, that is, if the rotation were 234 minutes instead of 24 hours; the centrifugal

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What experiment with a water-pail? What illustration by carriages? What illustration with soft clay? What effect has centrifugal force on our earth? What is said of its increase?

force and gravitation would be equal, and all bodies would be destitute of weight, and if the centrifugal force were to be still further increased, all oodies would fly off into space, or rise up and form a ring like that which surrounds Saturn.

11. It is believed that Saturn's double ring, was formed by the great centrifugal force of that planet, raising the lighter materials from its surface, where they are exactly balanced between the centrifugal force and the attraction of gravitation.

LIV. The centrifugal force of any body increases with its distance from the centre of the circle in which it moves: it also increases with the weight of the body in motion.

Illustration. Thus the force of the mud flying from the coach-wheel, fig. 17, increased by increasing the distance from the circumference of the wheel from the centre, or in other words, by increasing the size of the wheel, the force would also be *evidently increased*, by increasing the size of the globules of the mud, which are in this case the moving body.

CENTRE OF GRAVITY.

LV. The *Centre of Gravity* of a body, is that point, about which all its parts do in any situation exactly balance each other, so that if a body be suspended or supported by the centre of gravity, it will rest in any position.

Illustration 1. Thus a rod or beam of wood, being supported by its middle like a weighing beam, the two sides will exactly balance each other, and be at rest. See the wood-cut fig. 19.

Fig. 19.

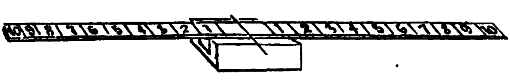
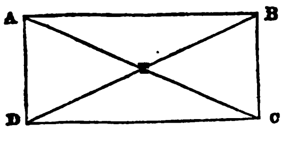


Fig. 20.

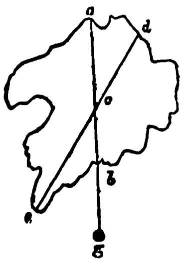


2. Instead of a beam, a wheel may be used, and if uniform in its structure and material, its centre of gravity would be exactly in the middle, or in its centre of motion.

3. The centre of gravity in a parallelogram is at the place of crossing of two lines drawn from the opposite corners. Thus, in fig. 20, the lines A C and D B

What remark of Saturn and his rings? LIV. What is said of the increase of centrifugal force? and how is it illustrated? LV. Define the centre of gravity. 1. How is it illustrated? What illustration by a wheel? What by a parallelogram?

Fig. 21.



cross at E, which is the centre of gravity of the parallelogram A B C D.

4. The centre of gravity of any irregular body, as *a e b d*, fig. 21, is found by suspending it from any point as *a*, and dropping a plumb line *a g*, from the point *a*, the centre of gravity must be somewhere in the ling *a g*. Now suspend the body at another point, as at *d*, and drop the plumb line as before, it will fall in the line *d e* and *c*; the point of crossing of the two lines is the centre of gravity.

LVI. The *Centre of Motion* is the point about which the body moves; and a heavy body suspended on a centre of motion will be at rest, if the centre of gravity is directly under, or above, the centre of motion.

Fig. 22.

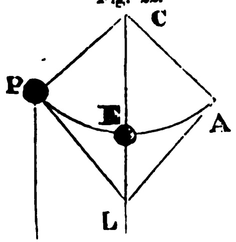


Illustration. If a heavy body E, fig. 22, hangs by a string on a centre of motion C, the action of gravitation at E is in the direction E L, contrary to the direction in which the string acts to prevent the body from falling. In this position, therefore, the opposite forces being equal in contrary directions, destroy each other, and the body is at rest. But if the body is at P, one of the forces acts in the direction P C; and the other in the direction P L, that is, in a direction oblique to each other, whence the body will move in the diagonal of the parallelogram formed by P C, P L. And since in all cases, without the aid of mechanical powers explained hereafter, the force which sustains any body must be equal to its weight, the centre of gravity can only be at rest when these forces are in the same line of direction, that is, when the centre of gravity is directly under, or directly above the centre of motion.

LVII. If a line be drawn perpendicular to the horizon, from the centre of gravity of a body, it is called the *Line of Direction*, because it is the line which the centre of gravity would describe if the body were suffered to fall.

LVIII. While the line of direction falls within the base

What by an irregular body? LVI. Describe the centre of motion. Give the illustration. LVII. Describe the *Line of Direction*. When will a body stand, and when will it fall?

upon which the body stands, the body cannot fall: but if it fall without the base the body will tumble.

Fig. 23.

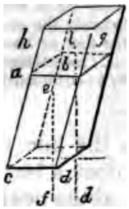
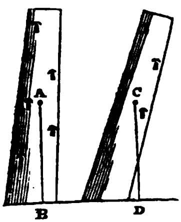


Illustration 1. The inclined body *a b c d*, fig. 23, whose centre of gravity is *e*, stands firmly, because the line of direction *e f*, falls within the base. But if the body *a b g h* be placed upon it, the centre of gravity will be raised to *l*, and then the line of direction *l d* will fall out of the base; of course, the centre of gravity is not supported, and the whole must fall.

Observation. This proves the injurious effect of rising in a coach or boat in danger of oversetting, the centre of gravity being thereby raised, and the line of direction thrown out of the base. Whereas, in such circumstances, the proper course is to lie down in the bottom, so as to bring the line of direction, and consequently the centre of gravity, within the base, and thereby remove the danger of oversetting.

Fig. 24.

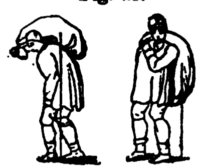


2. A column, an obelisk, or a steeple might incline somewhat from the perpendicular, and yet stand firm. From the inspection of the annexed figures it will appear that the inclination of a column might be greater than is represented in the first figure, where the line A B falls within the base, without endangering the stability of the body; but it must be less than that in the second figures, where the corresponding line C D falls without the base.

3. When a porter carries a load, his position must be regulated by the centre of gravity of his body and the load taken together. If he bare the load on his back, the line of direction would pass beyond his heels, and he would fall backward. To bring the centre of gravity over his feet, he accordingly leans forward, fig. 25.

If a nurse carry a child in her arms, she leans back for a like reason.

Fig. 25.



4. When a load is carried on the head, the bearer stands upright, that the centre of gravity may be over his feet. In ascending a hill, we appear to incline forward, and in descending, to lean backward; but in truth we are

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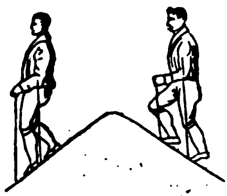
Give the illustration. What illustration by a tower? What illustration by a porter? What illustration by a load on the head, and by ascending a hill.

Fig. 26.



standing upright with respect to a level plane. This is necessary to keep the line of direction between the feet, as is evident from fig. 26.

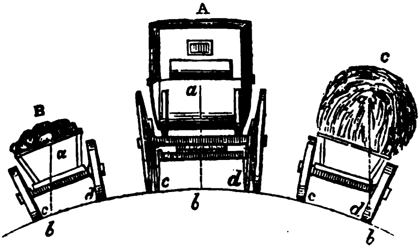
5. If a man rise from a chair, he is seen first bending forward, so as to bring the centre of gravity forward over the feet or base, when he also raises the body; If he attempts to rise too soon before the body is sufficiently advanced he falls back again.

LIX. The broader the base, and the nearer the line of direction is to the centre of it, the more firmly does a body stand; and the narrower the base of a body, and the nearer the line of direction is to the side of it, the more easily it is overthrown.

Observation. Hence, a sphere is easily rolled along; and a narrow or pointed body is with difficulty made to stand.

Illustration 1. The ease or the difficulty with which any thing may be upset, depends chiefly on the height of the centre of gravity above the base, together with the condition just mentioned with respect to the line of direction. This the following illustration will render manifest. On a highway, level in the middle, but sloping towards the sides, let there be a coach on the level and a wagon on each slope at the side, one wagon loaded with hay, and another with stones, the centres of gravity and lines of direction will be as shown in the figures.

Fig. 27.

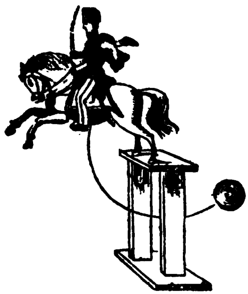


Centre of pressure in carriages.—A, a coach standing on a level; B, a cart loaded with stones on a slope; C, a wagon loaded with hay on a slope; *a*, *a*, *a*, the centres of pressure; *a b*, line of direction; *c d*, base.

Hence it is obvious that the hay-wagon must upset, because the line of direction falls without the base; that the coach is very secure because the line of direction falls in the base; and that the stone-cart, though the centre of pressure is low down, is not very secure because the line of direction falls very near the outside of the base.

What illustration by rising from a chair? LIX. When do bodies stand firm, and when are they easily overthrown? What is said of upsetting? What results obviously?

Fig. 28.



Hence it may be perceived why vans and stage-coaches, if heavily loaded at the top, will be very liable to be overturned, while a similar or greater weight placed low down will prove a security from danger; and on this principle "safety-coaches" have been constructed, with receptacles for heavy luggage under the bodies of the vehicles.

The effect of placing the centre of gravity of a body in a very low situation is shown in vibrating figures, such as that represented in the margin, and other toys for the amusement of children, formed on similar principles.

LX. If a plane be inclined on which a heavy body is placed, the body will slide down upon the plane, while the line of direction falls within the base; but it will roll down, when that line falls without the base.

Fig. 29.

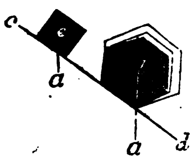


Illustration 1. The body *c*, fig. 29, having the line of direction *ea* within the base, will only slide down: but the line of direction *ba* of the body *b* falling out of the base, that body rolls down the plane.

2. When the line of direction falls within the base of our feet, we stand; and most firmly, when it is in the middle; but when it is out of the base, we fall unless we step out, and this is the principle of walking.

LXI. The common centre of gravity of two or more bodies, is the point upon which they would rest in any position.

Fig. 30.

Illustration. If the centre of gravity of two bodies, AB. fig. 30, be connected with the straight line AB, the distances AC, and BC, from the common centre of gravity, C, are inversely as the weight of the bodies A and B; that is, the point of C will be as much nearer to A than to B, as A is heavier than B; that is AC is to BC as B is to A.

What is said of stage-coaches loaded at top? LX. What is perceived from this principle? What does fig. 28 show? What is said of a heavy body on an inclined plane? Illustrate by fig. 29. LXI. What is said of the common centre of gravity of two bodies? Give the illustration.

Example. Suppose A to be a ball of 12 pounds, and B a ball of 4 pounds, and the length of AC, to be five inches; then BC will be fifteen inches; for it will be, 5 : BC :: 4 : 12, or 4 × 12, or 4 × BC = 5 × 12 = 60, and BC = 60 ÷ 4 = 15.

Observation. If the centre of gravity of three or more bodies is required, it may be found in the same manner—by first finding the centre of gravity of any two, and considering that as the centre of gravity of one body, of which and the third body the centre of gravity may be found the same as before; and so on, for any number of bodies.

PENDULUMS.

LXII. A PENDULUM is a heavy body, generally of metal, suspended by a wire or cord, so as to swing backward and forward, and each swing, or movement in one direction is called a *vibration* or *oscillation.*

Observation. The principle of the pendulum, of which the common clock pendulum is a familiar instance, was first noticed by Galileo, by observing the hanging chandeliers in the church of Pisa to continue vibrating for a long time, after being disturbed by some accidental cause. Galileo was led to investigate the laws of this phenomenon, and out of what had been in one shape or another before men's eyes, from the beginning of the world, this day, a philosopher produced one of the most valuable instruments for regulating the affairs of men.

LXIII. The times of the vibrations of a pendulum, are nearly equal whatever be the length of the vibration.

Fig. 31.

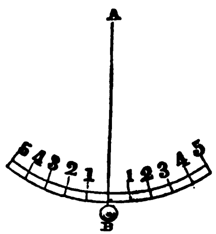


Illustration. Thus there will be but little difference in the time taken up by the ball B, in moving from 5 to 5, 4 to 4, &c., on each side of the line A B, till it stops entirely. It is this remarkable property of the pendulum that makes it so useful as a measure of time; and clocks, or time-keepers, regulated by a pendulum, are nothing more than trains of wheel-work kept in motion by weights and so arranged as to register the beats of pendulums which oscillate seconds. The whole show how many oscillations or swings of the pendulum have taken place, because at every swing a tooth of the last wheel is allowed to pass, and if the wheel has sixty teeth, as is common in clocks, it will turn round once for every sixty vibrations. And, if the spindle or axis of this wheel project through the dial-plate or face of a clock, with a hand fastened on it, this hand will be the second hand of the clock. The other wheels are so connected with the first, and the number of teeth so proportioned that the second one turns sixty

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LXII. Describe the pendulum, and its vibration. Give the history of the origin of the principle? LXIII. What is said of the vibrations of pendulums. Give the illustration.

times slower than the first, and this will be the minute hand; a third wheel moving twelve times slower than the last will constitute the hour hand.

LXIV. The length of the pendulum influences the time of its vibration; long ones vibrate slower than short ones.

LXV. A pendulum of a little more than 39 inches, will beat seconds: one four times that length, will beat double seconds, or, once in two seconds, and, one of one fourth the length, will beat half-seconds.

LXVI. The same pendulum will vibrate more slowly on the equator, than at the poles, because the attraction of gravitation is less powerful at the equator.

Corollary. Therefore, a pendulum to vibrate seconds, must be shorter at the equator than at the poles.

LXVII. As heat expands, and cold contracts all metals, a pendulum rod is longer in warm, than in cold weather; hence, timepieces gain time in winter, and lose in the summer.

Fig. 32.

LXVIII. To counteract the effect of expansion and contraction, various contrivances have been employed. One of the best, is the *gridiron pendulum*, so called from its construction; it being composed of rods of different metals, which expand differently under the same changes of temperature.

Illustration. Thus brass dilates twice as much by the same degree of heat as steel; hence, if the pendulum E B D, be lengthened in summer, by the expansion of the steel bars A and C, it will be shortened just as much by the superior expansive power of the brass bar B, so that the whole length of the pendulum, will remain nearly the same throughout the year.

LXIV. What is said of the length of pendulums? LXV. What lengths are required to beat seconds, double seconds, and half seconds? LXVI. What effect have equatorial or polar situations? What inference? LXVII. What effect has heat? LXVIII. How are changes of temperature counteracted? Describe the gridiron pendulum.

MECHANICAL POWERS.

LXIX. The *Mechanical Powers* are certain agents applied to engines, or machines founded upon the laws of motion, which machines enable men to overcome resistance in raising weights, moving bodies, &c.

LXX. The principal moving powers or agents, are, 1 animal power, 2 wind, 3 water, 4 steam, 5 springs and weights.

Observation. Hence, the terms *man-power*, *horse-power*, *steam-power*. In large cities where fuel is cheap, and where much power is required, steam is most frequently used; where small power is required, dogs are frequently employed for driving machinery. Thus, in large iron-works, steam is employed where there is not a good water-power; in the manufacture of machine and hand-cards, where all the machinery is light it is frequently propelled by dogs. In low or level countries windmills are frequently employed; thus, on or near the seacoast windmills are frequently used to manufacture grain into flour; to pulverize medicines; watches are propelled by springs, and clocks by weights.

LXXI. Three circumstances are to be considered in treating of mechanical contrivances :—

1. The *weight* to be raised, or the *resistance* to be overcome.

2. The *power* by which it is to be raised: and

3. The *instruments* employed.

Observation. The principles of the mechanical powers are such, that, wherever power is gained something is lost to counterbalance it; Thus, if power is gained, generally, time, space and velocity are lost. Thus, if I can lift a hundred pounds with my hands, I may be able to lift by a lever one thousand pounds, but it will take ten times as long to lift it through the same space.

LXXII. There are usually reckoned six mechanical powers: the lever; the wheel and axle; the pulley; the inclined plane, the wedge; and the screw.

THE LEVER.

LXXIII. The Lever is a bar of iron or wood, supported by and moveable on a round centre called a *ful-*

LXIX. Define mechanical powers. LXX. What are the principal moving powers? What is the observation? LXXI. How many circumstances to be considered? and what are they? What is the observation? LXXII. Give the number and names o the mechanical powers. LXXIII. Describe and illustrate the lever.

crum having the *resistance* at the short arm, and the *power* at the long arm.

Fig. 33.

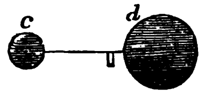


Illustration. Let *c d* be a lever, resting on a fulcrum or prop, then *d* will represent the weight, *c* the power.

LXXIV. The mode of action of the lever may be further illustrated by observing what takes place when two or more boys amuse themselves with a see-saw, or vertical swing.

Fig. 34.

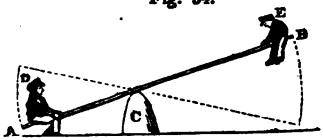


Illustration. Here the plank A B forms a lever, of which the block C is the fulcrum, and in order for the plank to be equipoised, it must be shifted into such a position that the greater weight of the boy D nearest the fulcrum, may be compensated by the greater distance from that fulcrum of the boy E.

LXXV. There are *three* kinds of levers, distinguished according to the different positions of the *fulcrum* and the moving *power* with respect to each other.

LXXVI. In the *first* kind of lever the fulcrum is in the middle, the power at one extremity and the weight to be raised at the other.

Fig. 35.

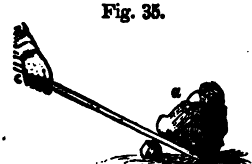


Illustration. Thus, in fig. 35, *b* is the fulcrum, *a* the weight, and *c* the power.

LXXIV. Illustrate its mode of action. LXXV. Describe the kinds of lever LXXVI. Describe the first kind of lever.

[illegible] cylinder with projecting spokes, [illegible] common axis.

Illustration. [illegible] accompanying figs. 44 and 45.

Fig. 44.

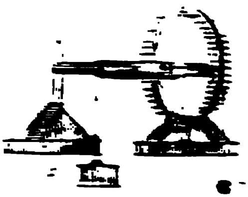
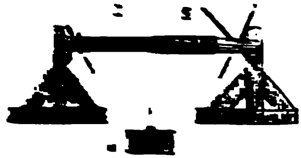


Fig. 45.



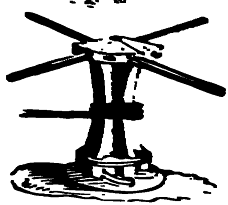
LXXX. The advantage gained is in proportion as the circumference of the wheel is greater than that of the axis; or as the diameter of the wheel is greater than the diameter of the axis.

Illustration. If the diameter of the wheel, fig. 44, or the length of the spoke, fig. 45, be four feet, and the diameter of the axle only 8 inches, then the power of one hundred pounds, or the strength of a man applied to the spoke or circumference, [illegible] will balance a weight w, of six hundred pounds.

In this case, as in the lever, the power will move over six times as much space as the weight, when the machine is put in motion.

LXXXI. A capstan is a cylinder of wood, with holes in it, into which bars are put to turn it round. The bars are made to act something like the spokes of a wheel; fig. 46.

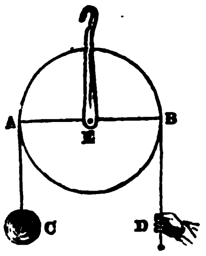
Fig. 46.



Observation. The capstan is chiefly used on board ships, for lifting the anchor, and for doing any other heavy work. The common winch or crank, by which a grindstone is turned, or the key with which a clock or a watch is wound up, is really a wheel and axle.

LXXX. What is the advantage gained? How illustrated? LXXXI. Describe the capstan. What remark on the use of the capstan?

Fig. 47.

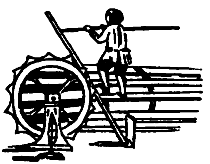


LXXXII. The *Wheel and Axle* is a modification of the lever.

Illustration. That such is the case, may be shown by the accompanying wood-cut, where C, represents a ten-pound weight, suspended over a wheel, by the line D, held in the hand, which it is evident must pull with a force of ten pounds to counterbalance the weight. Now E, is the fulcrum of the lever A E B, of which A E, and E B, are the equal arms requiring equal weights to balance them.

LXXXIII. The *Tread-wheel*, is a modification of the wheel and axle, in which a number of persons continually stepping on the circumference of the wheel, makes it revolve by their weight, as represented in the wood-cut below; similar machines are adopted in many ferry-boats moved by horses instead of men: these are denominated horse-boats.

Fig. 48.

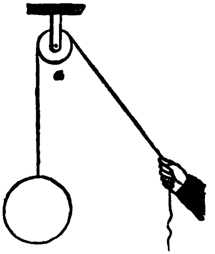


LXXXIV. Sometimes it is desirable in order to gain great advantage to use a very large wheel and small axis, which would often be inconvenient on account of the room required, and in such case the *combination* of *wheels* is substituted.

Illustration 1. In fig. 49, (p. 44,) three wheels are seen connected. Teeth on the axle *a*, of the first wheel, acting on six times the number of teeth in the circumference of the second wheel, turn it only once for every six turns of the first wheel; and in the same manner the second wheel, by turning six times, turns the third wheel once; consequently, if the proportion between the wheels and their axes be preserved in all three, the third turns once, the second six times, and the first thirty-six times; and as the diameter of the wheel 1, to which the power is applied, is three times greater than that of the

LXXXII. What is the principle of the wheel and axle? How is it illustrated? LXXXIII. What is said of the treadwheel? LXXXIV. What is said of the combination of wheels?

Fig. 52.



2. There are some cases where a pulley of the kind represented in fig. 52, may be used to great advantage inasmuch as the pin or support of the wheel *a*, bears half of the weight. By using the hands then to pull with a force equal to half the weight of the body, a man can support or raise himself with great ease, as represented in the wood-cut, Fig. 53.

A man by a pulley thus employed may let himself down into a deep well, or from the brow of a cliff, and elevate himself again without aid, and without danger. Cases have often occurred where a fellow-creatures life might have been saved by this simple contrivance, and many other important objects gained. For example, how easy would it be to reach or escape from the elevated windows of a house on fire, by such a pulley, which might be found and used where ladders could not be obtained. The cranks, and handles of bell-wires, seen in the corners and walls of our parlours, are instances of the fixed pulley, with a short lever which is the handle.

Fig. 53.

Observation. The pulley is arranged among the simple mechanical powers; but when several are connected, the machine is called a *system of pulleys*, or a *compound pulley*

The most extensive application of the pulley, is in building the rigging of ships, and on ship-board, for lading and unlading, hoisting anchors, masts, sails, &c. They were also used formerly by surgeons, for reducing dislocated joints, but improved philosophy can dispense with this apparatus.

LXXXVII. Pulleys are either *fixed* or *moveable*.

Observation. The fixed pulley gives no mechanical advantage, but is used only to change the direction of a power. By it a man may raise a weight to any height, without moving from the place in which he is, as a stone to the top of a building, otherwise he must ascend with the weight.

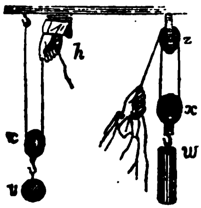
LXXXVIII. The moveable pulley represented by *x*, fig. 54, is fixed to the weight, and rises and falls with it, and the advantage gained by it is as 2 to 1.

Illustration 1. The reason of this is evident; for in raising the weight one inch, foot, or yard, both sides of the rope must be shortened as much, that

What is the observation on pulleys? LXXXVII. How many kinds and what their uses? LXXXVIII. What is said of the moveable pulleys? Give the two illustrations?

is, the hand *h* must move through two inches, feet, or yards; which shows, as before, that the space through which the power moves, must always be in proportion to the advantage gained.

Fig. 54. Fig. 55.

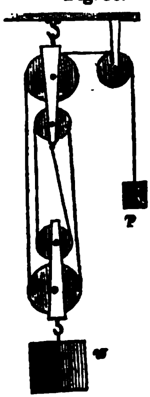


2. When the upper *fixed* blocks, *z*, fig. 55, contains *two* pulleys, which only turn on their axis, and the lower moveable block, *x* contain also two, which turn and rise with the weight *w*, the advantage gained is as *four to one*. For each pulley in the lower block will be acted upon by an equal part of the weight, and since in each pulley that moves with the weight a double increase of power is gained, therefore the advantage gained, is as *four* to *one*.

LXXXIX. In general the advantage gained by pulleys is found by multiplying the number of moveable pulleys by 2.

Illustration. A weight *w* of 72 lbs. may be balanced by four moveable pulleys by a power of nine pounds, because, 72 divided by 8 gives 9; but in this case the power, when put in motion, will pass over 8 times as much space as the weight, that is, to raise the weight one foot, the hand must move through 8 feet.

Fig. 56.



XC. Where there is but one rope running through the whole, a better method is to multiply the power *p*, by the number of folds in the rope which supports the weight *w*.

Illustration. In Fig. 56, there are four folds of the rope, and a power of 100 lbs. at *p*, would support a weight of 400 lbs. at *w*. As the upper block or wheel is added for the purposes of giving direction and not being directly connected with the weight, the last fold which passes over it is not counted in estimating the power.

THE INCLINED PLANE.

XCI. The inclined plane is merely a plane surface in-

LXXXIX. How is the advantage of pulleys found? How illustrated? XC. What is the second mode of estimating the advantage gained in pulleys? How illustrated? XCI. Describe the inclined plane, and give the illustration

clined to the horizon, and is used to move weights, from one level to another. See fig. 57.

Fig. 57.

Illustration. In fig. 57, the plane is inclined, or descends in the direction *d a*, and the ball *e* if left to itself would roll down by the action of gravity, and the steeper the descent or the greater the inclination, with the greater force and rapidity it moves downward and the greater power is required to roll it up.

The inclined plane is often made by placing boards, or earth, in a sloping direction, and is of great importance in rolling up heavy bodies, as casks, wheelbarrows, &c., heavily loaded.

XCII. The force with which a body descends upon an inclined plane, is to the force with which it would descend perpendicularly, as the height of the plane is to its Weight.

Fig. 58. Fig. 59.

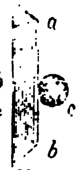
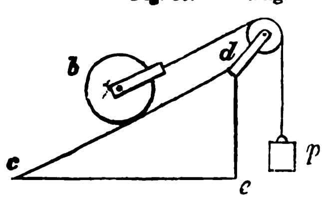


Illustration 1. If the plane *a b*, fig. 58, be parallel to the horizon, the cylinder *c* will rest on any part of it wherever it is laid. But if the plane be placed perpendicularly as *a b*, fig. 59, the cylinder will descend with its whole weight, and would require a power equal to its weight, to keep it from descending. Or if the plane be inclined to the horizon as *a d*, fig. 57, and *three* times the length of the perpendicular *b d*, the cylinder *e* will be supported by a power equal to a *third* part of its weight.

Fig. 60.



2. If the plane *c d*, fig. 60, be twice as long as its height *e d*, one pound at *p*, acting over the pulley, would balance two pounds any where between *e* and *d*; If the plane *c d*, were three times the length of *d e*, then one pound at *p*, would balance 3 pounds any where on the plane *c d*, and so of all other qualities and proportions.

3. A horse drawing on a road where there is a rise of one foot in twenty is really lifting one-twentieth part of the whole load besides overcoming the friction and other resistance of the carriage; hence, the importance of making roads as level as possible, and hence the errors of the earlier engineers and surveyors, in constructing turnpikes, and roads directly over hills for the sake of straightness considered vertically, whereas by going round the base of the hills, they would scarcely have gone a greater distance and would have avoided all rising and falling. See the wood-cut, fig. 61.

XCI. What is the method of estimating the force of descent? give the first illustration? Give the second illustration? What is the remark of going round hills.

Fig. 61.

No. 1.

No. 2.

In the above fig. 61, No. 1, represents a vertical section of a road passing over a hill, and No. 2, a horizontal section of a road passing round the foot of the hill; both go the same distance, but one ascends and the other avoids the hill.

4. An intelligent driver in ascending a steep hill, on which there is a broad road, winds from side to side of the road, to render the ascent less steep, and thus favours his horses.

5. The railways of modern times are fine illustrations of this subject. They are made perfectly level, when practicable, so that the drawing horse, or steam-engine has only to overcome the friction of the carriage or locomotive; where heavy loads are passing only in one direction, as in moving coal, ore, &c., from mines, the rails are made to slope a very little leaving to the horse or other power, only the office of regulating the movement; such is the case at the Lehigh coal-mines, in Pennsylvania; there is a railroad, on an inclined plane, 8 miles in length, and descending at the rate of 100 feet a mile. Down this railway, the cars previously loaded with coal, at the mines, are carried by their own gravity, at the astonishing rapidity of a mile in three minutes.

6. A hogshead of merchandise, which 20 men could not lift directly, is often moved into or out of a wagon by one or two men, by an inclined plane, constructed by means of a plank, one end of which rests on the wagon, and the other on the ground.

7. In some canals, as on the Morris canal in New Jersey, the loaded canal-boats instead of being raised by means of a lock, are carried up an inclined plane, by water power.

What illustration concerning coach-drivers? What remark on the railways of the moderns? What remark respecting hogsheads of merchandise? What is said of canals?

8. It is supposed that the ancients, and especially the Egyptians must have used the inclined plane, to assist in elevating and placing those immense masses of stone, which still remain from their times, as the wonder of all succeeding ages.

9. Our common stairs, are inclined planes in principle; but being steep, are cut into horizontal and perpendicular surfaces, in order to afford a firm footing.

THE WEDGE.

XCIII. The Wedge may be considered as two equally *inclined planes* united at their bases. The advantage gained is in proportion as the length of the two sides of the wedge is greater than the back, or as the length of one side is greater than half the back.

Fig. 62.

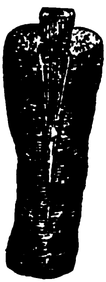


Illustration 1. The wedge is used for a great variety of purposes, but more especially for splitting blocks of wood or stone, and for squeezing strongly as in the oil-press; for raising great weights, as when a ship of war is raised by driving wedges under the keel.

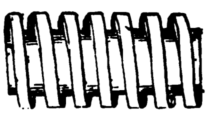
2. An engineer in London, having built a very lofty and heavy chimney, found after a time, that it was beginning to settle on one side, but by driving wedges under the same side, he at length restored it to perpendicularity.

3. Nails, awls, needles, &c., are examples of the wedge, as well as cutting instruments, such as knives, razors, axes, chisels; some of these are often used in the manner of a saw, which acts as a series of small wedges. The sharpest razor may be pressed directly against the hand with considerable force, with perfect safety; but the slightest drawing movement will cause the instrument to bury itself in the flesh.

THE SCREW.

XCIV. The screw is a cylinder, with a spiral protuberance coiled round it, called a thread, which will be readily understood by inspecting the wood-cut below.

Fig. 64.



What illustration concerning the ancients? And what of our common stairs? XCIII. Describe the wedge, and give the first illustration? What illustration concerning tall chimneys? Give the substance of the third illustration? XCIV. Describe the screw.

XCV. The form of the screw may also be represented by cutting a slip of paper in the form of an inclined plane, and winding it round a cylinder of wood, as a common lead pencil, it will form a spiral protuberance like the thread of a common screw.

Fig. 64.

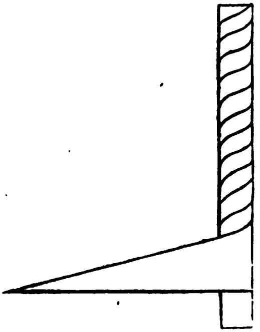


Illustration. See the wood-cut, fig. 64.

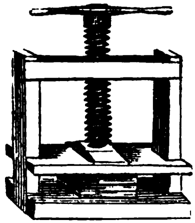
Observation. The screw is considered as a modification of the inclined plane, and is used with a lever or winch to assist in turning it; and then it becomes a compound engine of great force, either in pressing bodies closer together, or in raising great weights. In fact, a screw is simply an inclined plane coiled round a cylinder, and the nut or perforated body which moves up or down a screw, moves up or down an inclined plane in a circular instead of a rectilinear direction.

XCVI. The advantage gained by this kind of mechanical power, is in proportion as the circumference of the circle made by the lever or handle of the screw is greater than the distance between the threads of the screw.

Illustration 1. See the accompanying wood-cut, fig. 65. If the distance of the spiral threads from each other be half an inch, and the handle of the screw that is the lever projects 36 inches, then the circle described by the lever will be about 228 inches, or 456 half inches, consequently a force of one pound at the end of the lever will balance a resistance of 456 pounds; hence, the longer the handle, and the nearer the threads of the screw are to each other, the greater the power gained by the screw.

XCV. In what other way can the principle of the screw be explained? XCVI. What is the estimation of the advantage gained by the screw? Give the illustration.

Fig. 65.



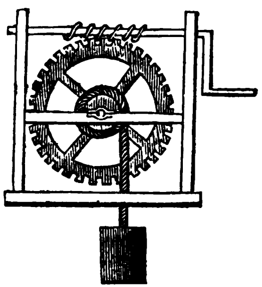
2. Screws are much used in presses of all kinds; as in those used in pressing oil and juices from various vegetable substances, as linseed, rape-seed, almonds, apples, grapes, sugar-cane, castor-beans, &c. They are also used in packing cotton, by which means a large and spongy bale, a few of which would fill a ship, is reduced to a compact mass heavy enough to sink in water, and in the common printing-press, they force the paper strongly against the type.

3. A screw is the great agent in our mints for coining money, in letter-copying machines—It is the screw which brings together the iron jaws of a smith's vice; and although the friction of the screw is very considerable it is still a very useful power.

4. A common corkscrew is the thread of a screw without the spindle, and is used, not to connect opposing forces, but merely to penetrate and fix itself in the cork.

XCVII. A perpetual or endless screw is the name given to screws acting on the teeth of a wheel, so as to produce a continued motion. See the woodcut, fig. 66

Fig. 66.



Observation. A little reflection on the preceding explanation of the na-

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Give the substance of the second illustration. Give the third. What is said of the corkscrew? XCVII. What is an endless screw? What is the observation?

ture and properties of the mechanical powers, will sufficiently prove that, in a strict philosophical point of view, the real and original mechanical powers are not more than two in number; being all referable to the lever and inclined plane; so that all the others are only species of these two; the wheel and axle, and the pulley being species of the lever; and the wedge with the screw being species of inclined plane. And likewise, the various philosophical writers do not agree with respect to the number of the simple mechanical powers; some reckoning two, others five, and some have enumerated seven, &c. It is, however, immaterial whether those powers are considered all primitive and distinct from each other, or not; for the theory always remains true and the same.

GENERAL REMARKS.

XCVIII. The real advantages of all the mechanical powers may be summed up as follows:—

One man's effort or any small power, which is always at command, by working proportionably longer can perform the work of many men acting at once, whom it might be expensive, inconvenient, or impossible, to bring together, at any one time.

XCIX. A ship's crew of a few individuals, easily weighs a heavy anchor, by means of the capstan.

C. A solitary workman by means of a screw or engine, can press a sheet of paper, against the type so as to take off a clear impression; to do which without the press, the direct push of fifty men would scarcely be sufficient; and besides these fifty men would be idle and superfluous, except just at the instant of pressing, which occurs only at considerable intervals; hence the screw is said to do the work of fifty men, for it is as useful.

CI. A single man with a crowbar, (as a lever,) can move a great log of wood, which it would have required twenty men to accomplish without such means; and, though the one man takes twenty minutes to do the work that twenty men would have done in one minute and as the twenty might not be needed again in the course of the day, therefore one man with his crowbar, has done the work of twenty men.

XCVIII. What are the advantages of the mechanical powers? XCIX. What is said of ship's crew? C. What of the printing-press? CI. Give the illustration of CI.

FRICTION.

CII. In all machines it is an important circumstance to consider the resistance arising from the friction among the parts of the machine.

Illustration 1. In the steam-engine where the rubbing parts are numerous, the loss of power from friction often amounts to one third of the whole, which allowance is generally made in estimating the power of a machine.

2. If it were not for the friction encountered, men walking on the ground or pavement, would always be as if walking on ice; and over rivers, that now flow calmly, would be frightful torrents; hence the friction upon the gravelly bottom and banks of a river greatly retard the rapidity of the current.

CIII. The following are the means used to overcome or diminish the friction of rubbing surfaces.

Illustration 1. By making the rubbing surfaces smooth.

2. By interposing some lubricating substances between the rubbing parts; as oils for the metals, soap, grease, blacklead, &c., for the woods. There is an amusing illustration of this subject, in the holyday sport of soaping a lively pig's tail, and then offering him as the prize of the one who can catch him and hold him fast by his slippery appendix.

3. A third method consists in the use of wheels as in carriages, instead of dragging a load along on the ground; castors on household furniture are used for the same purpose.

4. Large blocks of stone and even houses, are often moved to a very considerable distance by placing them on rounded cylinders or logs of wood, resting on a hard pavement, or on timbers.

5. Of all rubbing surfaces, the joints of animals considering the strength, frequency, and rapidity of their movements, have the least friction; we indeed study and admire the perfection found in these without being able to succeed in closely imitating them.

HYDROSTATICS.

CIV. Hydrostatics is a term used to explain the laws of the denser fluids such as water, oils, quicksilver, &c.

CV. The word fluids, is a very general term applied to air, water, caloric, &c. Fluids have hitherto been divided into *elastic*, as air, and *non-elastic* as water, but the terms

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CII. What is said of friction? Give the illustration? What is said of the effects of friction in walking, and of friction in running water? CIII. What is the first means in overcoming friction? What is the second? What is the third means used in overcoming friction? What is the fourth? and what is the fifth? CIV. Define hydrostatics? CV. Define the term fluid?

aeriform bodies for the first, and *liquids* for the second, are more appropriate.

CVI. Liquids form a class of bodies intermediate in properties between those of aeriform bodies and of solids.

Illustration. The chief distinction between solids, liquids, and gaseous bodies is, that in the first, the particles have greater cohesion than in the second, and the third are destitute of this property. There is no necessary difference in kind between the particles of solids, liquids, and gases; thus ice, water, and steam, are composed of the same kind of particles, but in ice they are fixed, in water they easily roll upon each other, and in steam they tend to fly off into space.

* CVII. Liquids were for a long time considered as incompressible bodies, but recent experiments have shown that the fact is not so.

Illustration. An experiment was made by an association of scientific gentlemen at Florence, 1661, which was relied on as conclusive evidence of the incompressibility of water; they subjected water to a very great pressure in a globe of gold, until the liquid oozed through the pores of the metal as if it had been leather; but other experiments by Mr. Canton, in 1761, and more recently by our countryman Mr. Perkins now in England, and the celebrated Professor Oersted, of Copenhagen, have proved that 12 cubic inches of water, under a pressure of 30,000 pounds to the square inch, which is equal to 960,000 pounds on the whole, reduced the 12 cubic inches to 11; hence it is said that by the pressure of 30,000 pounds to the square inch water is diminished in bulk one twelfth.

CVIII. Liquids are subject to the same laws of gravity with solids; but their want of cohesion occasions some peculiarities. The parts of a solid are so connected as to form a whole, and their weight is concentrated in a single point, called the centre of gravity: but the atoms of a liquid gravitate independently of each other.

CIX. Liquids press not only like solids, perpendicularly downward; but also upward, sidewise, and in every direction.

Experiment 1. Take a glass tube, open at both ends, put a cork in one end, and immerse the other in water. The fluid will not rise far in the tube; but the moment the cork is taken out, it will rise to a level with the surrounding water; which proves the pressure upward.

2. Take a very narrow glass tube, open at both ends, and dip the lower extremity beneath the surface of quicksilver, so that a small portion of it

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CVI. Define the application of the term liquid. What is the illustration? CVII. What is said of compressibility of liquids? Give the illustration of this subject. CVIII. What is the difference between the pressure of solids and liquids? CIX. What is their law of pressure? Give experiments 1, 2 and 3.

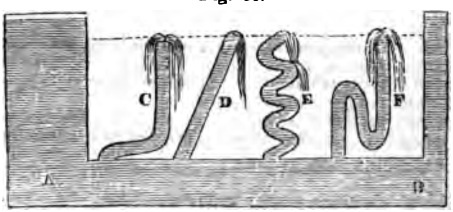
may rise into the bottom of the tube; then stopping the upper extremity carefully with the finger, lift the tube, and holding it vertically, plunge the open end into a deep jar filled with water, when it will be found that the pressure of that liquid from below upward will not only keep the quicksilver suspended, when the finger is removed from the top of the tube, but on letting it sink gradually in the jar, the quicksilver will rise to a height bearing a certain relation to the depth of the lower end of the tube beneath the surface of the water.

Fig. 67.

3. Let a circular brass plate A B, fig. 67, be adapted to the bottom of a glass cylinder and fitted accurately by grinding, or by covering its upper surface with moist leather, so that when the cylinder is immersed in the jar of water F F, and the plate is held by the string E close to the bottom of the cylinder, none of the liquid can enter it. If then it be immersed to such a depth that the weight of the vertical column of water which it displaces shall be equal to the weight of the brass plate, the latter will remain suspended though the string be let go, the upward pressure of the water being sufficient to keep the plate from falling.

CX. A liquid kept in an open vessel, will assume a surface parallel to the horizon whatever be the form of the vessel, and will remain at rest.

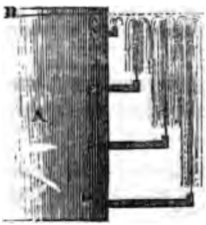
Fig. 68.



CX. What is said of fluid levels?

Illustration 1. In the preceding figure, let A B represent a glass vessel, closed except at the two raised extremities, and filled with water to a height above the horizontal line; then suppose four differently shaped tubes C D E F, open at both ends, to be inserted in the oblong part of the vessel, with their upper extremities not rising so high as those standing at the sides; it will be found that the liquid will pass laterally into the tube C, ascend directly in D, and circuitously in E, while it both descends and ascends in F, rising equally in all the tubes, and spouting out till the water is reduced in the side tubes to the level of the summits of the internal ones, when the equilibrium being established the liquid will remain at rest. Thus it follows that any number of columns of a liquid, freely communicating, whatever may be their respective diameters and figures will always have the same vertical height.

Fig. 69.



2. Let water spout upward through a pipe having a small orifice inserted into the bottom of a deep vessel; it will rise nearly to the height of the upper surface of the water in the vessel. The resistance of the air, and of the falling drops, prevents it from rising perfectly to the level.

Let A represent a cistern filled with water, at the constant height B C, then in four bent pipes D E F G, be inserted at different distances below the surface, the jets will all rise to nearly the same level, that of the line B C.

CXI. In constructing canals, railroads, &c., it is of great importance to ascertain the true horizontal level.

Illustration 1. This is generally done by an instrument called the *spirit-level.* It consists of a glass tube *a c*, fig. 70, hermetically sealed and previously filled with spirits of wine, excepting a small air bubble *b*. When the tube is horizontal the bubble has no tendency to move one way or another, but the slightest inclination will cause the bubble to rise to the highest end.

Fig. 70.

Fig. 71.

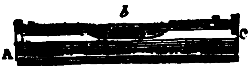
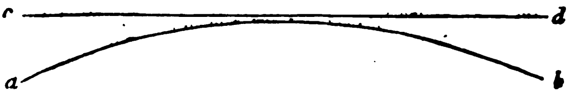


Fig. 70, represents the glass tube with its air bubble in the middle. Fig. 71, the same enclosed in a glass case, and when thus protected it is mounted on surveyor's compasses, and other instruments to assist in placing them horizontally upon the ground.

Give the first illustration. The second. CXI. What application of this principle? Describe the spirit level. Illustrate it by the figures.

2. A hoop surrounding the earth would bend away from a perfectly straight line eight inches in a mile. In cutting a level canal, therefore which may be considered as a part of a hoop, there must be every where a falling from the straight line in the proportion abovementioned, in consequence of the rotundity of the earth. This will be better understood from the figure 72, seen below.

Fig. 72.

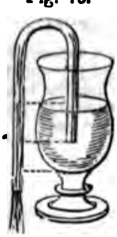


In fig. 72, *a b*, represents a section of the surface of the earth, 2,000 miles in extent, and *c d*, a horizontal, or level section of the same extent, in which the extremities of the lines *c d*, and *a b*, are nearly three thousand feet apart, from the rounded surface of the earth.

CXII. It is on the principle of the water-level that the syphon acts, in discharging liquids from higher to lower levels.

Illustration. The syphon consists of a tube bent in the form of the letter U, but, with one of its legs longer than the other, and is used in discharging liquids from vessels that are not moved with convenience.

Fig. 73.



To use the syphon, while the ends of the instrument are upward, fill it with the liquid, and cover each extremity with the fingers, and in this state plunge the shorter leg into the vessel as represented in Fig. 73, and as soon as the leg is plunged below the surface of the liquid in the vessel, the fingers may be removed, and the liquid will flow out of the longer leg of the syphon, so long as it remains lower than the horizontal level of the fluid within the vessel.

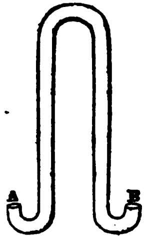
Observation. The syphon can never carry the liquid more than 32 or 33 feet higher than the level of the fountain whence it springs, because the pressure of the atmosphere will not sustain a higher column; this will be explained under the department of pneumatics.

CXIII. The Wirtemberg Syphon, shown in the following figure, when once filled with liquid, will remain so, and hence may be hung up in that state ready for use.

Illustration. One leg A, being plunged into a vessel of the liquid to be drawn off, it will escape through the open extremity B, in consequence of the additional pressure of the liquid in the vessel at A; thus it will appear that this syphon acts somewhat differently from those of the common construction, though it is applicable to similar purposes.

Give the second illustration of the level. CXII. What is the principle of the syphon? Give the illustration and how it is to be used. What is the observation on syphons? CXIII. Describe the Wertemberg syphon.

Fig. 74.



CXIV. There are springs situated often in the sides, or base of mountains, which run for a time, and then cease and after an interval, flow again and stop as before. These are denominated *intermitting springs*, and produce their effect on the principle of the siphon.

Fig. 75.

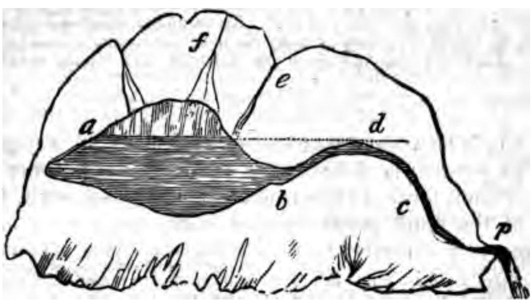


Illustration. Fig. 75 is intended to represent a hill, or mountain, containing an intermitting spring, acting the part of a siphon. The letters *a b* represent a fissure or hollow place in the rock, filled to the line *a d* with water, having an outlet *b d c p*, in the form of a siphon, while it is supplied with water through the fissures *a f* & *e*. As soon as the reservoir *a b* is filled by the fissures *a f* & *e*, as high as to the line *a d*, the stream will begin to

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CXIV. What are intermitting springs? Illustrate the intermitting spring.

flow out at p, and will continue till the level in the reservoir is reduced nearly as low as b, when the air will supply the place of the water, and the stream at p will cease, until the reservoir be again filled as high as the line $a\,d$, when it will commence running as before. That part of the hollow above the line $a\,d$, is constantly filled with air.

The hollow, above the line $a\,d$, is supposed not to be filled with the water at all, since the syphon begins to act whenever the fluids rises up to the bend d.

Observation. The syphon may be made available for the purpose of conveying water over the side of a pond or reservoir into another, provided the latter is on the same or a lower level than the former. It was thus very ingeniously applied by a French engineer, M. Garipuy, in 1776, to discharge the surplus quantity of water from the canal of Languedoc, when it had been raised above the proper level by the influx of water at the mouth of the river Garonne during a storm.

CXV. The fluid-level is seen on a vast scale in the discharge of the waters of mighty rivers, from a higher to a lower level.

Observation. A very slight declivity suffices to give the running motion to water. Three inches of fall in a mile in a smooth and regular channel causes a velocity of about three miles an hour, the Ganges which receives its waters from the Himalaya mountains, the highest in the world, is, at eighteen hundred miles from its mouth, only eight hundred feet above the level of the ocean; and to fall this comparatively small distance, it requires, in its long and winding course, more than a month. Rivers and all running waters tend to reduce the height of the land, and by filling up the ocean gradually to raise its level. The Ganges alone, it is estimated, transports from the mountains annually to the ocean a bulk of earthy matter sixty times greater than the great pyramid of Egypt, which is 500 feet high, and covers 11 acres of ground.

CXVI. The pressure of the same fluid is in proportion to the perpendicular height, and is exerted in every direction; therefore, at the same depth, all the parts or particles of the fluid press against each other with equal force in every direction.

Experiment 1. If a bladder full of air be immersed in water, then the perpendicular pressure is manifest, for the deeper the bladder is immersed, the more will its bulk be contracted.

2. An empty bottle being corked, and by means of a weight, let down a certain depth into the sea, will be broken, or the cork will be driven into it by the perpendicular pressure. But a bottle filled with water, wine, &c., may be let down to any depth, without damage, because in this case the internal pressure is equal to the external.

What observation on the useful application of syphons? CXV. What remark of fluid-level on large scale? What is the observation illustrative of this principle? CXVI. What relation is observable between the height of a fluid and the perpendicular pressure? What simple illustrations may be given of this principle?

Observation. At the depth of 32 feet below the surface of the sea, a diver has been calculated to be pressed with a weight equal to about 28,000 avoirdupois pounds; yet as that pressure is distributed all over his body, and the human body consists mostly of non-elastic fluids or of solids, he does not feel any remarkable inconvenience from such a pressure.

CXVII. The pressure of any liquid is in proportion to its perpendicular height and the width of its base.

Fig. 76.

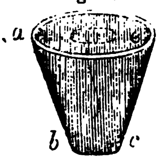
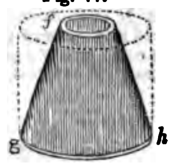


Fig. 77.

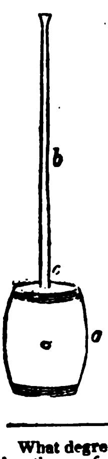


Experiment 1. In the vessel *a b*, fig. 76, the bottom *c b*, does not sustain a pressure equal to the quantity of the whole fluid, but only of a column, whose base is *c b*, and height *b a*.

2. In the vessel *f g*, fig. 77, the bottom *g*, sustains a pressure equal to what it would be if the vessel were as wide at the top as the bottom.

3. The truth of the above law is illustrated in the experiment of bursting a wine-cask, with only a few ounces of water.

Fig. 78.



Suppose a cask *a*, already filled with water, and the tube *b c*, twenty or thirty feet long, screwed tightly into its top—the tubes will contain but a few ounces of water, yet by filling the cask and then pouring water through the tube it will press upon the inside of the cask first oozing through the pores of the wood and finally bursting it.

The same apparatus would also illustrate the upward pressure of fluids, by making a small aperture at the top of the cask, through which the water would be forced to a considerable height—according to theory, it would rise as high as it extends in the tube, but in practice the resistance of the air, and the flying drops prevent it from rising so high.

In practice it has been ascertained that if the tube be twenty feet long, and the internal diameter a half an inch, the water through an aperture in the cask would be forced a little more than eighteen feet high. On this principle artificial fountains are frequently constructed, the long tube *b*, terminates at top in a large reservoir, and at the bottom it often runs along under ground, until it approaches the spot, and then ascends and terminates in a small aperture through which the water spouts by the pressure of the column in the tube *b*.

What degree of pressure does a person sustain at the depth of thirty-two feet below the surface of the sea? CXVII. What is the pressure of a fluid in a vessel? Illustrate it by the figs. 76, and 77. Give the experiment with a wine-cask. How may we illustrate upward pressure? How do theory and practice differ here?

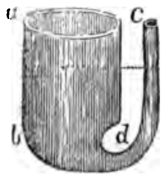
Observation 1. Hence may be calculated the pressure upon, and the strength required for, dams, cisterns, pipes, &c.

2. The *pressure* of fluids differs from their *gravity* or *weight* in this; the *weight* is according to the *quantity*, but the *pressure* is according to the *perpendicular height*.

CXVIII. The hydrostatical paradox is this: that any quantity of fluid, however small, may be made to counterpoise any quantity, however large.

Experiment. If to the wide vessel *a b*, fig. 79, a tube *c d*, be attached, and water be poured into either of them, it will stand at the same height in both. Of course, the small quantity in *c d*, balances the large quantity in *a b*. But this is only a paradox in terms, because the action of the fluid is downward not upward.

Fig. 79.



CXIX. The same principle of upward pressure is also shown in a striking manner by the *hydrostatic bellows*.

Fig. 80.

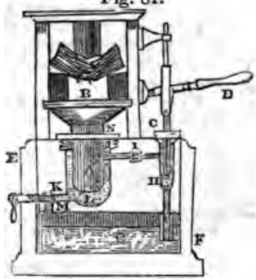
Illustration. This instrument consists of a small long tube into which water is poured and enters the body of the apparatus at its side near to the bottom. The body consists of two strong boards connected together by strong water-tight leather. If the tube hold an ounce of water, and have an area one thousand times less than that of the top of the bellows it will balance a thousand ounces on the bellows. If mercury were substituted for the water used in this machine, the effect produced would be 14 times greater then with water, because it is 14 times heavier than that fluid; and if a man stand on a large bellows of this kind he may raise himself by blowing into the top of the tube.

CXX. The power of the pressure of a column of water was applied by Brahma, in the construction of his hydraulic press.

What observation follows? CXVIII. Define the hydrostatic paradox. CXIX. Describe the hydrostatic bellows. CXX. Describe Brahma's press.

Illustration 1. This machine consists of a solid mass of masonry or strong wood-work, E F, firmly fixed; and connected by uprights with a cross-beam. B, represents a strong table, moving vertically in grooves between the uprights, and supported beneath by the piston A, which rises or descends within the hollow cylinder L, and passes through a collar N, fitting so closely as to be water-tight. From the cylinder passes a small tube, with a valve opening inward at I, and D is a lever which works the piston of the small forcing-pump C H, by which water is drawn from the reservoir G, and driven into the cylinder L, so as to force up its piston A. At K is a valve, which being relieved from pressure, by turning the screw which confines it, a passage is opened for the water to flow from the cylinder, through the tube M, into the reservoir G, allowing the piston to descend.

Fig. 81.



2. The amount of pressure capable of being made is estimated by the relative size of the two pistons A and H.

If the small piston, is half an inch in diameter, and the large piston one foot in diameter, then the pressure on the latter will be 576 times greater than that on the former. Therefore, if we suppose the pressure of the small piston to be one tun, the large piston will be forced up against any resistance, with a pressure equal to the weight of 576 tuns. It would be easy for a single man to give the pressure of a tun on the small piston by means of the lever, and therefore a man, with this engine, would be able to exert a force equal to the weight of near 600 tuns.

It is evident, that the force to be obtained by this principle, can only be limited by the strength of the materials of which the engine is made. Thus, if a pressure of two tuns be given to a piston, the diameter of which is only a quarter of an inch, the force transmitted to the other piston, if three feet in diameter, would be upwards of 40,000 tuns; but such a force is much too great for the strength of any material with which we are acquainted.

A small quantity of water, extending to a great elevation would give the pressure above described, it being only for the sake of convenience, that the forcing-pump is employed, instead of a column of water.

SPECIFIC GRAVITY.

CXXI. By the *specific gravities* of bodies, is meant

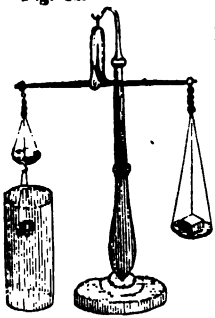
How is its power estimated? CXXI. Define specific gravity.

the relative weights which equal bulks of different bodies have in regard to each other.

Illustration 1. Thus a cubic foot of cork is not of equal weight with a cubic foot of water, or marble, or lead: but the water is four times heavier than the cork, the marble 11 times, and the lead 45 times; or, in other words, a cubic foot of lead would weigh as much as 45 of cork, &c., &c.

2. If we fill completely a tumbler with water, and then drop in it a pebble or any other heavy body that will sink, it is quite evident that a quantity of water will run out equal in bulk to that of the body immersed.

Fig. 82.



3. Hence where a body sinks in water, it displaces or pushes away a quantity of the liquid equal to its own bulk, which liquid must have pressed against the solid to buoy it up, and thus caused the body to weigh less when immersed in water, than in air.

Experiment. If any body *x*, a mass of gold for instance, be suspended by a hair from the bottom of one scale of a weighing beam, as seen in figure 82, and be balanced by weights put into the opposite scale, and a tumbler of water be then lifted under the solid body *x*, so as to immerse it in the liquid, it will be pushed up, or supported by the water, with a force equal to the weight of the water which it displaces; and in order to bring the beam horizontal, a weight precisely equal to that of the water displaced must be removed to the opposite scale.

Illustration 4. Suppose the gold weighed 19 grains in the air, and when immersed in water, it required 1 grain in the opposite scale to balance it, or it lost 1 grain, by being weighed in water—now if we ascertain how many times the 1 grain, the weight lost by weighing the gold in water, may be had in 19 grains, the weight of the gold in air, the answer will be the specific gravity of gold,

Thus, ... 1)19

19. the specific gravity of gold.

The instrument represented in fig. 82 is called the *Hydrostatic Balance.*

CXXII. In taking specific gravities of bodies, we make use of some one as a standard by which we compare all others. Pure water is the standard for solids and liquids, and common air, the standard for all aerial bodies.

Illustration 1. When we say therefore, that gold has the specific gravity of 19, copper 10, and cork 1-4, we mean these substances are just so much heavier or lighter, than the standard by which they are compared.

2. In all cases of solids heavier than water—the specific gravity is ascer-

What is the first illustration? What illustration by the tumbler? What results from the above illustration? What experiment to illustrate the subject. Give the fourth illustration. CXXII. What is said of the standard of specific gravity? Illustrate by gold, copper, and cork.

tained by dividing the weight of the body in air, by that lost from weighing it in water.

Example. A guinea weighs 129 grains in air; by being weighed in water it loses 7 1-4 grains, which shows, that a quantity of water of equal bulk with the guinea, weighs 7 1-4 grains; divide 129 by 7 1-4, or 7.25, and the quotient will be 17.793, which proves a guinea to be 17.793 times heavier than its bulk of water.

Corollary 1. We hence easily deduce the methods of obtaining the specific gravities of all bodies, taking rain water as a standard, a cubic foot of which being uniformly found to weigh 1000 avoidupois ounces.

The weight which a body loses in a fluid, is to its whole weight as the specific gravity of the fluid is to that of the body. If a guinea weigh in air 129 grains, and on being immersed in water lose 7 1-4 of its weight, the proportion will be 7 1-4 : 129 : : 1000 to the specific gravity of a guinea. By this method, the specific gravities of all bodies that sink in water may be found, and expressed in a table.

2. Hence, if different bodies be weighed in the same fluid, their specific gravities will be as their whole weights directly, and as the weights lost inversely.

If a body to be examined consist of small fragments, they may be put into a small bucket and weighed; and then if from the weight of the bucket and body in the fluid, we subtract the weight of the bucket in the fluid, there remains the weight of the body in the fluid.

3. If the solid be lighter than water, then instead of removing part of the weights from the opposite scale (as in CXXI. *Exper.*) we add a heavy body to the solid x, suspended (See fig. 82), until it sinks, and note the weight which both together lose by immersion: this will be the weight of a bulk of water, equal to that of the two solids; now detach the lighter solid and ascertain the weight lost from the heavier by immersion; this will be the weight of a bulk of water equal to the heavier body; subtract this loss from that sustained by the immersion of both taken together, the remainder will be the weight of a bulk of water equal to that of the lighter solid. The proportion of the weight of the lighter solid to this remainder will determine its specific gravity.

4. The specific gravity of other liquids is obtained in various ways, but one of the best is to make use of a vial or flask, that holds 1000 grains of water, filled to a certain line marked on its neck, and this is to be done when the liquid is at a certain temperature, namely, 62° of Fahrenheit's thermometer; the specific gravity of any other liquid is found by filling the flask with it as before, and reducing it to the same temperature which may be done by placing in a vessel of water recently drawn from the well, which is generally of a right temperature; now weigh the whole, and the difference between this weight and that of the water, will be its specific gravity.

Example. Suppose it is pure sulphuric acid that we wish to examine, and we find that the measure of acid weighs 1840 grains; had it been 2000, the specific gravity would have been 2, or twice that of water, but it is now expressed, 1.840.

The same measure of alcohol, would weigh about 800 grains, and hence the specific gravity being less than that of water, which is taken as unity, and expressed thus: 1.000 would be represented by 0.800 which is equal to 800 parts in a thousand, 80 parts in a 100, or 8 parts in ten.

How is the specific gravity ascertained in bodies heavier than water? Give the examples? How in bodies lighter than water? How do we take the specific gravity of liquids? Give the examples.

CXXIII. Many liquids, differing in specific gravity, may be mixed by agitation so as to form a compound; but if the lighter liquid be poured gently on the surface of the heavier, they will for a long time remain distinct, but little action taking place, even where the surfaces meet. Every body knows that water may be mixed with port wine or spirits, both which are lighter than that liquid, as may be shown by the following experiments:—

Fig. 83.

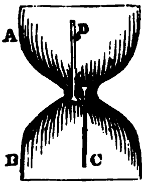


Illustration. Suppose A B to represent a double-bodied vessel the only communication between the upper and lower portions of which is through the tubes C and D; then if the part B be filled with water to the neck, and A with port wine, so as to rise above the tube D, still no mixture or alteration in the state of the liquids will take place, for the lightest occupying the highest situation will retain it undisturbed. But if the lower part be filled with port wine, and the upper with water, the former fluid will ascend through the tube D, and the latter descend through the tube C, till they have entirely changed places. A vessel of this construction, having the upper part transparent, and the lower part opaque, would form an amusing philosophical toy, by means of which might be exhibited an apparent conversion of water into wine. An analogous experiment may be made by taking a small bottle, with a long narrow neck, not more than the sixth of an inch in diameter, which is to be filled with spirit of wine, tinged red, by infusing in it raspings of sanders wood, or yellow, by putting into it a small quantity of saffron; the bottle thus filled with the coloured spirit is then to be placed at the bottom of a deep glass jar of water, when the spirit will be seen to ascend like a red or yellow thread through the water, till the whole has reached the surface.

CXXIV. Bodies, differing in specific gravity, and incapable of combination, may be shaken together in a vial, and mixed for a time, but will separate completely on being allowed to remain at rest. Such is the effect exhibited in the following mimic representation of the production of the four elements from chaos:—

Illustration. A glass tube, about an inch in diameter, closed at one end, or a deep vial, being nearly filled with equal parts in bulk of coarsely powdered glass, oil of tartar, proof spirit, and naphtha, or spirit of turpentine, the former spirit tinged blue, and the latter red,* the tube or vial must be

* The blue teint may be communicated to the proof spirit by adding a small portion of tincture of litmus; and the other spirit may be coloured with dragon's blood.

CXXIII. What happens when two liquids incapable of combination are shaken together? CXXIV. Describe the apparatus known by the name of the four elements.

secured with a cork; and when it is briskly shaken the four imaginary elements will form a confused dull-looking mass, but on setting the vial upright, and suffering it to remain undisturbed for some time, an entire separation will take place between the several portions of the chaotic mixture: the powdered glass at the bottom representing earth; the oil of tartar, floating above it, water; the spirit, with its cerulean teint, occupying the place of air; and the glowing naphtha at the top designed as an emblem of elementary fire.

CXXV. When two liquids, varying in specific gravity, are included in a bent tube, as represented in the annexed figure, they will not stand at the same height on both sides of the tube, like a single liquid; but their respective heights will be in the inverse ratio of their specific gravities.

Fig. 84.

Illustration. Thus, as any given bulk of mercury weighs nearly fourteen times as much as an equal bulk of water, one inch of mercury, M, would equipoise about fourteen inches of water, W, on the opposite side of the bent tube. Neither the form nor the dimensions of the tube are of any importance to the result of this experiment; for as in other cases of hydrostatic pressure, a small quantity of water may be made to counterbalance the larger quantity of the heavier fluid mercury, provided the column of water stands perpendicularly fourteen times as high as the column of mercury.

HYDROMETER.

CXXVI. The hydrometer is an instrument for taking the specific gravity of different liquids, and produces its effects by the depth to which it sinks.

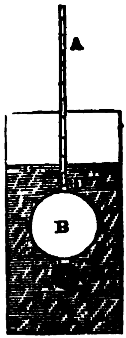
Observation. The apparatus and processes already given for ascertaining specific gravity, are adapted to give results, of extreme accuracy, which are always necessary for scientific purposes; but for ordinary purposes of commerce, or the arts, a more simple and easily-managed apparatus is used, which requires less time and less skill in the operation: such an instrument is met with in the hydrometer.

Illustration 1. This instrument, as represented on page 68, consists of a hollow glass ball B, with a smaller ball of metal C, appended to it, and which from its superior weight, serves to keep the instrument in a vertical position, to whatever depth it may be immersed in a liquid. From the large ball rises a cylindrical stem A D, on which are marked divisions of equal parts; and the depth to which the stem will sink in water, or any

CXXV. What occurs where the bent part of an inverted syphon is occupied by mercury, and one of the branches is afterward filled with water? CXXVI. What is the hydrometer? What are their special uses? Give the illustration.

other liquid fixed on as the standard of specific gravity being known, the depth to which it sinks in a liquid whose specific gravity is required will indicate, by the scale, how much greater or less it is than that of the standard liquid.

Fig. 35.



2. Hydrometers are used by dealers in wines, spirits, acids, and all commercial liquids, for ascertaining their comparative strength, and with the tables and directions accompanying them are easily used by the most unskilful hand.

3. It is a well-ascertained fact that water attains the utmost degree of density just before it freezes, its bulk being relatively less at 40 deg. of Fahrenheit or 8 deg. above the freezing point, than at any point either higher or lower in the scale.

The difference of the weight of a cubic inch of distilled water at 40 deg. and at 60 deg. is somewhat less than half a grain troy, whence it may be made to appear from calculation that a cubic foot of pure water, at its great density, weighs almost exactly 1,000 ounces avoirdupois, or 62 1-2 pounds. If, therefore, the specific gravity of water be represented by the number 1,000, each of the numbers in the following table will express the corresponding weights of a cubic foot of the several bodies included in it. Thus a cubic foot of pure gold would weigh 19,258 ounces avoirdupois, and an equal bulk of cork but 240 ounces.

4. *Specific Gravities of various Solids, Liquids, and Gases, as compared with Water at 60 Deg.*

Platina, laminated	22,069	Mercury, fluid	13,568
purified	19,500	solid	13,610
Gold, cast,	19,258	Lead, cast	11,352
hammered	19,361	Silver, cast	10,474
standard, 22 carats	17,486	hammered	10,510

By whom are hydrometers used? At what temperature is water at the greatest density? What is the weight of a cubic foot of water at its greatest density? What would be the weight in ounces of a cubic foot of platinum? Would a block of silver sink or swim in a bath of mercury? why?

Bismuth, cast . .	9822	Sea-Water .	1030
Copper, cast . .	8788	Ice . . .	930
Brass, cast . .	8395	Alcohol . . .	797
wire . .	8544	Proof Spirit . .	923
Nickel, cast . .	7807	Sulphuric Ether . .	734
Iron, cast . .	7207	Naphtha . .	708
malleable . .	7788	Linseed Oil . .	940
Steel, soft . .	7833	Olive Oil . .	915
tempered . .	7816	Oil of Turpentine .	870
Tin, cast . .	7291	Anise-seed . .	986
Zinc, cast . .	7190	Lavender . .	894
Sulphate of Barytes, or Ponderous Spar	4430	Cloves . .	1036
		Camphor . .	988
Oriental Ruby . .	4283	Yellow Amber . .	1078
Brazilian Ruby . .	3531	White Sugar . .	1606
Bohemian Garnet .	4188	Honey . .	1450
Oriental Topaz . .	4010	White Wax . .	968
Brazilian Topaz . .	3536	Caoutchouc, or Gum Elastic	933
Diamond . .	3521	Ivory . .	1917
Natural Magnet . .	4800	Isinglass . .	1111
Fluor Spar . .	3181	Milk, cow's . .	1032
Parian Marble, white .	2837	Butter . .	942
Carrara Marble, white .	2716	Mahogany . .	1063
Rock Crystal . .	2653	Lignum Vitæ . .	1333
Flint . .	2594	Dutch Box . .	1328
Sulphate of Lime, or Selenite	2322	Ebony . .	1177
Sulphate of Soda, or Glauber Salt	2200	Heart of Oak, 60 years felled	1170
Chloride of Sodium, or Common Salt	2130	White Fir . .	569
		Willow . .	585
Phosphorus . .	1770	Sassafras Wood . .	482
Nitrate of Potash, or Saltpetre	2000	Poplar . .	383
Sulphur, native . .	2033	Cork . .	240
Plumbago, or Black Lead	1860	Chlorine, formerly called Oxymuriatic Gas.	3.02
Coal . .	1270		
Sulphuric Acid, or oil of Vitriol	1840	Carbonic Acid, or fixed air	1.64
Nitric Acid . .	1271	Oxygen Gas . .	1.34
highly concentrated .	1583	Azotic, or Nitrogen Gas	0.98
Muriatic Acid, liquid, or Spirit of Salt	1194	Hydrogen Gas . .	0.08
		Atmospheric Air . .	1.21

5. If the specific gravity of water be represented by 1 instead of 1000, then that of platina will be 22.069, the last three figures being taken as decimals; the specific gravity of standard gold will be 17.486, that of sea-water 1.030, that of olive oil 0.915; and so on throughout the table, the three right hand figures representing decimal parts, except those denoting the specific gravities of the gases, the numbers of which must be thus altered to indicate the relations of their specific gravities to that of water:—

Would a piece of steel sink or swim in melted copper? What would be the effect of dropping a bar of lead into a pot of melted tin? How many times more matter in a cubic foot of saltpetre than in a like bulk of water? Which would sink most rapidly in water, a piece of flint, or one of native sulphur? When alcohol and linseed oil are put into the same vessel, which will occupy the higher part? Determine the same, with regard to water and honey—oil of terpentine and cow's milk—proof spirit and naphtha—sulphuric ether and oil of lavender. When the specific gravity of water is taken as unity, what must we consider the last three figures of each number in the table?

Water	1.
Chlorine	0.00302
Carbonic Acid . . .	0.00164
Oxygen Gas . . .	0.00134
Nitrogen Gas . . .	0.00098
Atmospheric Air . .	0.00121
Hydrogen Gas . .	0.00008

6. From the foregoing table it will appear that almost all bodies will float on the surface of mercury; gold and platina, and their alloys, being the only substances known of higher specific gravity than that metallic fluid, except one or two recently discovered metals of rare occurrence.* Many bodies will float on the surfaces of metal while in fusion: and thus earthy and other substances found in metallic ores rise in the state of scoriæ to the surface of the melted metal in the process of reduction. The lava discharged from volcanoes is a very dense fluid, partly metallic; and hence stones of vast bulk and weight are frequently seen swimming on its surface while it remains in the liquid state.

7. Most kinds of wood will float on water, and but few, as fir, willow, and poplar, on rectified spirit. The solution of a solid in any liquid increases its density: thus sea-water is heavier, bulk for bulk, than pure water; and an egg which will sink in the latter will swim in brine. Hence it sometimes happens that a heavy laden vessel, after having sailed in safety across the salt sea, sinks on entering the mouth of a river; owing to the inferior specific gravity of the fresh water.

ART OF SWIMMING, ETC.

The following remarks on the art of swimming &c., are from the excellent work of Professor Johnson, entitled the Scientific Classbook, which is so concise and yet so complete that the author has inserted it entire as well as the above table of specific gravities :—

1. The specific gravity of the human body during life is in most cases nearly the same with that of river-water, and coincides more exactly with that of sea-water; so that there are probably but few persons who would not float very near the surface of the sea in calm weather. Corpulent people are, bulk for bulk, lighter than those of sparer habits; for the adipose membrane or fat, of animals is inferior in specific gravity to water; while lean flesh unless the blood and other juices are drained from it, is of higher specific gravity than that fluid, and bone is proportionally much heavier than the soft parts of the body. Hence it might be inferred that the power of floating on water does not depend entirely on the relative specific gravity of

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* Iridium, a peculiar metallic substance discovered by Mr. Smithson Tennant, in combination with crude plantinum, has the specific gravity of 18.6; and Tungsten is a rare and difficultly fusible metal, the specific gravity of which is stated to be 17.2.

Which of the gaseous bodies has the greatest specific gravity? How many and which of them are specifically heavier than atmospheric air? Which is the lightest of gaseous substances? Why do the impurities of metallic ores rise, when melted to the surface of the mass? What is the nature of lava ejected from volcanoes? What effect on the specific gravity of any liquid is produced by dissolving in it a portion of any solid? To what maritime occurrence is this fact applicable? What is the relative specific gravity of the human body compared with fresh and with salt water respectively? Will a fat or a lean person float, with the greater facility in water?

the solids and liquids which enter into the composition of a human body; and accordingly we find that the body of a person destroyed by drowning or thrown into water immediately after death, will sink far beneath the surface; but after several days have elapsed, a body thus treated usually rises to the level of the water, in consequence of its having become specifically lighter than that fluid, from the accumulation of gas within the body, produced by incipient putrefaction. It is then chiefly owing to the air included in the cavities of the body during life, especially that portion contained in the lungs, that a man is enabled to float on the surface of a pond or river.

2. There are, however, some credible accounts extant of persons whose bodies were so much inferior in specific gravity to water, that they could not descend beneath its surface; not possessing that "alacrity in sinking," which may be literally attributed to most individuals. In 1767, there was a priest residing at Naples, named Paulo Moccia, whose extraordinary facility of flotation attracted much public attention. This ecclesiastic could swim on the sea like a duck; when he assumed a perpendicular position, the water stood on a level with the pit of his stomach; and it is stated that when dragged under the water by one or more persons who had dived for that purpose, as soon as he was released, his body would rapidly rise to the surface. It appears that the weight of this gentleman's body was thirty pounds less than that of an equal bulk of water. This peculiarity of conformation doubtless depended partly on his being extremely fat, and having very small bones; besides which, probably his lungs were capable of holding a larger quantity of air than is usual, and there might also have been an accumulation of air in the abdomen, arising from the disease called tympany, or from some other cause.

3. Most very corpulent people, who are at the same time strong and healthy, would perhaps find on trial that their bodies would float on water; and those who do not happen to be endowed with a superabundance of fat might still in almost all cases, with a little application, acquire the habit of floating with facility. The capability of breathing freely and at regular intervals is essentially requisite to enable a person to support himself on the surface of water. The head, and the upper and lower extremities are relatively heavier than the trunk of the human body; and the head especially, from the quantity of bone of which it is composed, is the heaviest part of the whole mass, yet unless the face at least be kept above water the respiration cannot be continued. It is therefore of the highest importance that all persons should be perfectly aware of the precautions necessary for this purpose; so that any one accidentally falling into the water, and being unable to swim, may be instructed how to escape a watery grave.

4. A person suddenly immersed in water, if not absolutely deprived of self-possession by fright, should, on coming to the surface after the first plunge, endeavour to turn on the back, carefully keeping the hands down, with the palms extended towards the bottom of the water, the legs being suffered to sink rather lower than the trunk; the only parts above the surface will then be the face and a small portion of the chest: at each inspiration more of the head and chest will rise above the water, and perhaps those parts will at first be for a moment covered with the aqueous fluid at the interval of expi-

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What will generally occur when a human body is thrown into water? Why does the body of a drowned person rise to the surface after being some days in the water? What extraordinary instance of specific lightness in the human body is recorded? On what circumstances did it probably depend? What operation is it necessary to perform while attempting to float on the surface? What measures should be adopted when one is suddenly immersed in water?

ration of the air. Every thing depends on making no effort to raise or keep out of water any part except the face, and endeavouring to keep the lungs, and consequently the chest as much expanded as possible, without using any irregular exertions in breathing; and it may be proper to caution persons thus circumstanced against struggling or screaming, as worse than useless; for in case any one who might yield assistance should be within call, it would be best to wait till the first alarm had subsided, and then the involuntary bather, conscious of comparative security, might use his voice with due effect, and without increasing the hazard of his situation.

5. But an acquaintance with the art of swimming can alone give a person perfect confidence of safety when by accident immersed in water. It is to be lamented that this is not a more general accomplishment; for it is one which must frequently prove of great utility; and it is much to be desired that it should become a branch of education at school for boys, as being of higher importance than the more fashionable arts of dancing, fencing, or even gymnastics.

6. It may be questioned whether written instructions alone would enable any one to acquire a facility in swimming; and admitting their utility, it would be inconsistent with the purpose of this work to afford them more than a cursory notice. In swimming, as in floating, the chief object of attention must be to keep the face above water, while the limbs are immersed: but from the different position required, it must be apparent that in swimming, not the face alone, but nearly the whole head must be sustained above the surface. In making a first attempt, the advice of Dr. Franklin may be followed, where he directs the learner to walk into water till he reaches a place where it stands as high as his breast, and dropping into the clear stream an egg; as soon as it has reached the bottom he is to lean forward, resting on the water, and endeavour to take up the egg, when he will become sensible of the upward pressure or resistance of the fluid; and finding that it is not so easy to sink as might have been previously supposed, the young adventurer would acquire confidence in his own efforts, the valuable result of experience.

7. Corks or blown bladders fitted by strings passing under the arms and across the chest, will afford material assistance in supporting the upper part of the body in a proper position; but they perhaps rather tend to retard than facilitate the progress of the learner, by leading him to form a false estimate of the resistance of the water; so that as soon as he makes an experiment without the corks he finds himself obliged to recommence his task, and study it on a different plan which might as well have been adopted at first. If, however, corks or bladders should be used, it is highly necessary that they should be secured from slipping down to the hips, and thus causing the swimmer to fall with the head vertically downward, and incur the most imminent risk of drowning.

8. As less exertion would be required in the position of floating than in that of swimming, there would perhaps be some advantage in acquiring the power of flotation, as above described, previously to attempting to swim. This having been effected, the learner might, instead of the common expedient of using corks, procure a two-inch pine plank, ten or twelve feet long, and placing it in the water, lay hold of it with one or both hands and push it

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What importance ought to be attached to the art of swimming? What is the first step towards the acquisition of that art? How may the learner be made sensible of the buoyant power of the water? What objection exists to the use of cork jackets and similar expedients to increase the buoyancy of the body when learning to swim? What use may be made of the swimming-board while learning the art?

before him while learning to strike with his legs. But this or any other artificial mode of practice that may be adopted, should be laid aside as speedily as possible, as the learner cannot too soon make himself acquainted with the full effect of the pressure of the fluid in which he is moving, and with his own strength and power of action; and till such knowledge is attained he will make but slow progress in the art of swimming.

9. The method of communicating buoyancy to solids of greater specific gravity than water, and enabling them to float in that fluid, by enclosing within them air or gas, is susceptible of application to a variety of useful purposes. It has accordingly been adopted in the construction of swimming-girdles, life-preserving belts, and air-jackets, which like the bladders noticed above, are merely bags of different shapes contrived so as to be inflated with air, and worn round the upper part of the body. Life-boats or safety-boats, as they are sometimes called, are rendered buoyant by forming in their sides air-tight cells or lockers, of sufficient dimensions to prevent the boat from sinking even when every other part of it is filled with water. It has recently been proposed to extend this principle to vessels of any size, and thus to prevent heavy laden merchant-ships or men-of-war from foundering at sea. The scheme consists in the employment of copper tubes of a cylindrical form, hermetically closed at the ends and sufficiently large and numerous to contain as much atmospheric air as would cause a ship to swim, when in consequence of having sprung a leak it would otherwise sink. It is stated by the inventor of these safety tubes, Mr. Ralph Watson, that an eighty-gun ship, even when immersed from leak, would not require the application of such tubes to a greater extent of displacement of water than would be sufficient to support 240 tuns of its immense weight.

10. Fish, in general, are provided by nature with a peculiar apparatus, which enables them to swim with the utmost facility, and to ascend close to the surface of the water, or descend to a considerable depth beneath it, by means of a membranous bag or bladder containing air, which they can distend or contract, and thus alter their specific gravity according to circumstances. The toad-fish it is said distends its stomach by swallowing air, to assist it in swimming, and becomes puffed up like a blown bladder, in the same manner as the globe or balloon fish.

11. An experiment has been previously related exhibiting the effects of the pressure of water upward in supporting a plate of metal, in contact with the lower extremity of an open cylinder, from which it may be inferred that solids of the highest specific gravity, as gold or platina, may be made to float on water or any other liquid, provided the floating body be of such a form that its upper surface may be protected from the pressure of the liquid by a column of air, the depth of which bears a certain proportion to the specific gravity of the solid. It is thus that a china tea-cup, though much heavier than an equal bulk of water, will yet float on that liquid if placed in it with its cavity upward and empty; but on pouring water into it, the cup will descend in consequence of the air within its cavity being displaced by the heavier fluid; till at length, when so much water has been poured in as to render the cup and water together heavier than a quantity of water equal to the space the cup occupies when immersed to its edge, it will sink to the bottom.

Explain the construction and use of the girdle employed for the same purpose? How are life-boats made incapable of sinking? How are Watson's safety tubes to be applied for the security of vessels at sea? To what is the power of vertical movement in fishes attributable? How may the heaviest of metals be made to float on the lightest of liquids? What quantity of water will it be necessary to pour into a floating basin in order to sink it to the water's edge?

12. A raft will float, because it is absolutely lighter than water, and a life-boat also for the same reason; but vessels in general, from the cock-boat to the largest man of war, owe their buoyancy to their concave form. Hence ships need not be built of fir or any light wood, since not only the heaviest woods might be used but even the heaviest metals, to construct floating vessels; and indeed steamboats made of sheet-iron have recently been tried, and found to possess the requisite properties for ploughing the waves with perfect facility and safety.

13. Floating bodies may be employed to raise heavy substances from the bottom of a river, pond, or basin of water. Thus a sufficient number of air-tight casks might be attached by ropes or chains to a large block of granite at the bottom of a river near its entrance into the sea, and the ropes being adjusted to such a length as to keep them strained tightly by the buoyancy of the casks at the lowest ebb of the tide, the block would be raised by the upward pressure of the casks at high water. Perhaps this method of raising or lowering ponderous masses of stone might be advantageously applied to practice in building bridges or piers within the tideway of a river.

14. The common method of regulating the supply of water conveyed by pipes into a cistern by means of what is called a ball-cock, depends on the action of a hollow globe of such dimensions relatively to the thickness of the metal as to keep it always floating on the top of the water in the cistern. A long wire is connected with the ball at one end, and at the other with a valve or stop-cock, on which it acts as a lever, opening it when the long arm of the lever is allowed to descend by the sinking of the ball attached to that end, when the water falls in the cistern, and on the contrary closing the valve, when, by the rising of the ball with the water, the cistern becomes full, and the lever presses on the valve or cock and keeps it shut, so that the cistern can never be filled beyond the proper height.

15. The power of floating bodies may also be applied in a different manner to the purpose of rendering buoyant other bodies attached to them; and among the various applications of this principle may be noticed the ingenious invention called the water-camel, used in Holland and also in Russia and at Venice, to enable large and heavy laden ships to pass shoals or sandbanks. The method of effecting this object consists of the application of two long narrow vessels adapted to the sides of the ship, and being hollow and water-tight they are filled with water, and then let down, and firmly secured on each side of the ship, after which the water is to be pumped out of them, and the whole mass, consisting of the ship and camel is thus rendered specifically lighter than before, and drawing less water than the ship alone did previously, the shoal or sandbank may be passed without danger of grounding.

16. The tendency of a floating body to assume a particular position when partly immersed in a liquid, and to retain or lose that position according to circumstances, may be elucidated by reference to the doctrine of the centre of gravity, as explained with relation to solids. When a solid body, specifically lighter than water, is placed on its surface, it will sink to a certain depth at which the absolute weight of the body is exactly counterbalanced

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How is the floating of a raft to be explained? How does it differ from that of an iron steamboat? To what useful purpose may the principle of flotation be applied in connexion with submarine operations? In what manner is the same principle applied to regulate the access of water to a cistern? Explain the construction and use of the water-camel. What takes place in regard to the centre of gravity of a floating body? How deep will such a body when specifically lighter than water always sink in the liquid? What name is given to the point at which the whole buoyancy of the liquid may be conceived to be concentrated?

by the upward pressure of the water. The point at which the entire weight of a body acts with greatest effect must be its centre of gravity; and that point at which the sustaining efforts of the liquid are most effective may be termed the centre of buoyancy, which must evidently coincide with the centre of gravity of the portion of water displaced by the floating body—and if the body be of uniform structure, with the centre of gravity of that part of it which is under water. A floating body cannot maintain itself in a state of equilibrium, unless its centre of gravity be situated in a vertical line over its centre of buoyancy, or immediately under that point. In the former case it will be in the state of instable equilibrium, and in the latter in that of stable equilibrium.

17. Hence the necessity of placing iron bars, stones, or other heavy substances in the hold of a ship by way of ballast when it is not freighted, or is laden with very light merchandise, in order that its centre of gravity may not be elevated too much above its centre of buoyancy. It is not requisite that the centre of gravity should be reduced below the centre of buoyancy, for though such a disposition would contribute to the stability of the vessel, the resistance to its passage through the waves would be so great as to make it sail heavily. In determining the proper situation of those points regard must be had to the shape and dimensions of a vessel as well as to the nature of the cargo or lading, and the manner of stowing it; and on a due attention to these circumstances its security and rate of sailing must in a great measure depend.

HYDRAULICS.

CXXVII. HYDRAULICS is the science which treats of the motions of liquids, their laws and the force they exert upon each other, and upon solids.

CXXVIII. The science will be treated under three divisions. 1. The motion of liquids through tubes and channels; 2. The means of producing motion in liquids, as in the various pumps, and other hydraulic engines; 3. The power derived from liquids in motion, whether produced naturally or artificially: this last department will include water-wheels, and various applications of water-power.

CXXIX. It is well known that water can be set in motion merely by its own gravity; as when it is allowed to descend from a higher to a lower level, either perpen-

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What will be the relative position of the centre of gravity and of the centre of buoyancy of a body floating at rest on the surface of water? Why are heavy articles stowed in the hold rather than on the deck of a vessel? CXXVII. What does the science of *Hydraulics* teach? CXXVIII. What is the division of the subject? CXXIX. How can water be put in motion, and how will it rise above its natural level?

dicularly or down an inclined plane. And by an increased pressure, as of the air, or by removing the pressure of the atmosphere, it will rise above its natural level.

In the former case, it will seek the lowest situation; in the latter, it may be forced to almost any height.

Observation 1. Water, by the process of evaporation, is made to ascend into the atmosphere in the form of vapour; afterward it descends in the form of rain, snow, or hail. Of that which falls on the land, part is absorbed by the roots of vegetables, and part descending into the earth, forms subterraneous streams which break out in springs.

2. Any part of a fluid at rest presses, and is pressed, equally in all directions. For each particle is disposed to give way on the slightest difference of pressure, consequently it presses equally in all directions, hence the lateral is equal to the perpendicular pressure of fluids.

CXXX. The velocity with which water spouts from a hole in the side or bottom of a vessel, is in proportion to *the square-root* of the distance from the hole below the surface of the water.

Example. If at the distance of one foot from the surface, the velocity is 1, another hole, four feet from the surface, would give the velocity of 2, and at 9 feet deep there would be a velocity of 3; here 2 is the velocity acquired and 4 feet the distance, and 2 is also the square root of 4, and 4 is called the square of 2; so also 9 feet is the square of 3, which last is denominated the square root of 9.

CXXXI. In consequence of the pressure of fluids, and the facility with which they rise to their first level, fluids may be conveyed over hills and valleys in bent pipes, to any height which is not greater than the level of the spring from which they flow.

Observation. It is generally stated in the books, that the ancient Romans were ignorant of this principle, and hence constructed aqueducts across valleys at an enormous expense, giving to the water a regular slope whereas at the present day a single pipe of cast iron is made to answer the same purpose, and even better, but the fact was not from the ignorance of the ancients of the principle but because they had not any materials that would resist the pressure of water in pipes, when descending through valleys.

CXXXII. Fountains are formed upon the same principle: if, near the bottom of any vessel, a small pipe bending upward be fastened, the water will spout out through the pipe, and rise nearly as high as the surface of the water in the vessel.

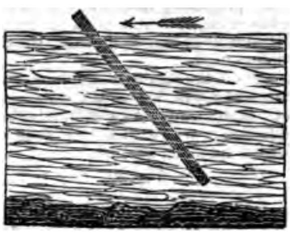
What are the laws of the pressure of fluids at rest? CXXX. What is the velocity of water spouting from a vessel? CXXXI. What is said of conveying water over hills? What is said of the knowledge of the ancients, on this subject? CXXXII. What is said of fountains?

Illustration. This proposition is illustrated in the subject of hydrostatics by fig. 69.

CXXXIII. In the passage of liquids through channels and through pipes, the velocity is very much impeded by friction, and this is increased with the roughness of the solid surface over which it flows.

Illustration. "It has been proved by experiment in contradiction to former theories on hydrostatics," says Mr. Lyell, "to be a universal law in running water that the velocity at the bottom of a stream is every where less than in any part above it, and is greater at the surface; also that the superficial particles in the middle of the stream, move faster than those at the sides. This retardation is produced by friction against the sides and bottom." The truth of this remark is seen, by watching the motion of particles seen floating with the current at different depths, those on the surface will move much faster than those near the bottom. The same principle may be illustrated by an experiment with a log of wood, one end of which is made heavier than the other by attaching a stone or piece of metal to it, so that it will sink near the bottom while the other end projects above the water—the upper end moving faster will cause the log to incline forward as seen in the woodcut.

Fig. 86.



CXXXIV. The effect of friction is even more perceptible in the passage of water through pipes than in open channels.

Illustration 1. Thus, a lead pipe with a smooth aperture, under the same circumstances, will convey much more water than one of wood, where the surface is rough, or beset with points. In pipes, even where the surface is as smooth as glass, there is considerable degree of friction, for in all cases the liquid is found to run more rapidly in the middle of the stream than upon the sides where it rubs against the tube. Sudden turns or angles in pipes for conveying water, diminish very much the quantity discharged in any given time by causing little eddies in the currents behind these angles in the same manner as a large rock in the bed of a river, will cause an eddy be

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CXXXIII. What is said of friction, and how illustrated? CXXXIV. Where is friction more perceptible? and how is the subject illustrated?

hind it. Hence, in all pipes for conveying water the bends of the pipes should be curves as large as convenient to diminish the friction.

2. An inch tube of 200 feet in length, placed horizontally will discharge only one fourth part as much water as a tube of the same diameter an inch in length; hence in all cases where it is proposed to convey water to a distance in pipes, there will be a great disappointment in respect to the quantity actually delivered, unless the engineer takes into account the friction, and the turnings of the pipes, and makes large allowances for these circumstances. If the quantity to be actually delivered ought to fill a two inch pipe, one of three inches will not be too great an allowance, if the water is to be conveyed to any considerable distance.

3. In practice, it will be found that a pipe of two inches in diameter, one hundred feet long, will discharge about five times as much water as one of one inch in diameter of the same length, and under the same pressure. This difference is accounted for, by supposing that both tubes retard the motion of the fluid, by friction, at equal distances from their inner surfaces, and consequently, that the effect of this cause is much greater in proportion, in the small tube, than in the large one.

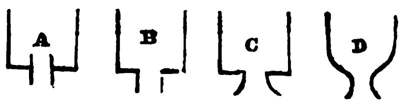
CXXXV. Friction is further illustrated by the passage of water through the sides or bottoms of vessels.

Illustration 1. It has been ascertained from experiment that a greater quantity of water will be discharged in a given time from the side or bottom of a vessel, through a short projecting tube, than from a simple aperture of the same dimensions. The tube, however, must be entirely without the vessels, as in fig. B, for if it is continued inside, as at A, the discharge will be lessened instead of being augmented.

2. Much also depends on the figure of the tube and that of the bottom of the vessel, since more water will flow in the same time through a conical or bell-shaped tube as C, than through a cylindrical tube.

3. A still further advantage was gained by having the bottom of the vessel rounded as in D, and the tube bell shaped.

Fig. 87.



CXXXVI. The second division of hydraulics, includes the various means of producing motion in liquids. This head embraces all kinds of engines used for raising water to a higher level as pumps, &c.

CXXXVII. All the different methods hitherto adopted for raising water, may be comprehended under five heads: 1st, the direct application of mechanical power, as the common

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What illustration by an inch tube 200 feet long? What proportion will be found in practice? CXXXV. How is friction farther illustrated? Give the first and second illustrations? CXXXVI. Describe the second division of hydraulics. CXXXVII. What are the different methods hitherto adopted to raise water?

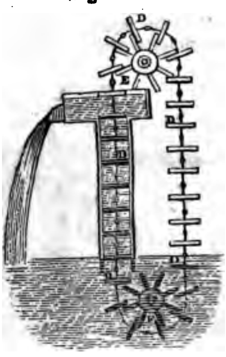
rope and windlass; 2d, by means of the pressure of theair, as in common sucking pumps; 3d, by compression as in forcing pumps; 4th, by weight or momentum of the water

CXXXVIII. Probably one of the earliest processes resorted to for raising water, was the common bucket and rope, either raised by the hands, or drawn up by a windlass, as in our common draw-wells. But the comparatively small quantity of water that can be raised at once by the use of a single bucket confines its employment to domestic or occasional purposes.

CXXXIX. The chain-pump is a much more efficient engine, though very similar in its mode of action to the preceding.

Illustration. The figure below indicates the form of this apparatus and consists of a number of flat plates or disks of wood or metal, usually square, and connected together through their centres by an iron rod, with joints between each board, so as to permit them to turn with nearly the same freedom as if they were connected by a chain. By attaching a winch to the upper wheel, these disks or plates drawn up by the revolving chain, form so many buckets filled with water, which they carry up and discharge into a cistern above, or when used as they commonly are on ship-board, into a pipe that may discharge it again into the sea. The machine may be set in motion by a winch, or other means applied to turn the upper wheel. The chain-pump will act with greater effect when the cylinder can be placed obliquely than when its direction is exactly vertical.

Fig. 88.



CXXXVIII. What were the earlier methods adopted? CXXXIX. What is the chain-pump?

Fig. 89.

CXL. The rope-pump is a less efficient modification of the chain-pump or bucket-engine. It is composed of wheels, one under water and another above water. Fig. 89, *a b*, and this is turned by the crank *d*

The rope generally used for this purpose consists of loosely spun horsehair, or yarn, and produces its effect by the friction of the rope with the liquid and depends almost entirely upon the great rapidity of the motion.

Observation. This apparatus is but a rude species of bucket pump, and by no means deserving the place it has formerly held in the list of hydraulic machines.

CXLI. The *cochlion* or *Archimides' screw*, said to have been invented by this philosopher, was used for draining the lands of Egypt about 200 years before the Christian era.

Illustration. This instrument may be understood by supposing a flexible tube bent round a cylinder of wood or metal representing the thread of a screw as seen in fig. 90. The lower extremity being immersed in a reservoir of water, the liquid will enter the tube and by turning the cylinder by means of the crank the various positions of the hollow screw thread are made to vary their position so that the liquid is forced up to the highest part of the cylinder where it is discharged into a proper receptacle, as represented in the wood-cut below.

Fig. 90.

CXL. Describe the rope-pump. What is the observation? CXLI. What is the Archimides' screw? Give the illustration.

CXLII. The second division includes instruments used to raise water chiefly by means of the pressure of the atmosphere, and comprises the various kinds of pumps, and other engines used for this purpose.

CXLIII. The COMMON or suction PUMP consists of a pipe open at both ends, in which is worked a moveable piston, that fits the bore exactly, and is provided with two *valves*, one in the piston which is moveable, and the other below it which is fixed; these are called by the workmen the upper and lower *boxes*.

Fig. 91.

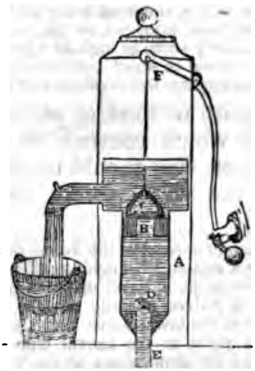


Illustration. The suction-pump sometimes consists of two hollow cylindric pipes A and E, the latter of which usually terminates below in a perforated ball, through which the water in the well enters freely into the suction-pipe; and at its other extremity is a valve D, opening upward, and affording a communication, when open, with the upper pipe A. In this pipe constituting the barrel or body of the pump, the piston B, moves air-tight vertically, and by its valve C opening upward, it permits the water to pass above it and be discharged at the spout. Now suppose the piston to be at the bottom of the barrel in contact with the valve D, on lifting the former by depressing the lever handle of the pump, connected with the piston-rod at F, the valve C will be closed by the pressure of the air above, and a vacuum being thus formed in the barrel, the same pressure on the surface of the water in the well, will drive it up the suction-pipe, and raising the valve D, the water will enter the exhausted barrel, whence by depressing the piston the valve D will be shut, and that at B rising, the water will pass upward and be discharged through the spout. The first effect of working such a pump must be to form a partial vacuum in

CXLII. What is the second division of hydraulic instruments for raising water? CXLIII. What is the common pump? Illustrate the suction-pump by the figure.

the barrel of the pump, and the upper part of the pipe E, and it will be only after the whole of the included air has been expelled through the piston-valve, and replaced by water in the pipes, that the liquid begins to flow, the atmospheric pressure* below taking full effect, while the equivalent pressure above is counteracted by the manual force applied to the handle of the pump.

CXLIV. The suction-pump cannot raise water beyond the extent of the action of atmospheric pressure, the utmost limit of which is about thirty-four feet.

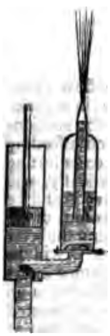
Illustration. Therefore the height of the valve D, above the level of the water in the well must never exceed that distance; and unless the pump be accurately constructed, so that the piston in its descent fits close to the bottom of the barrel, so as to form a perfect vacuum in its ascent, the water will not rise to the extreme height in the suction-pump. It must appear somewhat paradoxical, that though this will be the effect when the pump is in the best working order, the valves, and pipes being air-tight, yet a pump, the suction pipe of which has been damaged, so that a small quantity of air can enter, will raise water nearly twice as high as a good pump.

In this instance the column of liquid becomes much lighter from the admixture of air, and thus requires less pressure and force to elevate it.

CXLV. The third method of raising water is that of the forcing-pump which consists of a barrel, a plunger, and two fixed valves, that should be air-tight, and so disposed as to let the water freely rise, but prevent its return.

Illustration 1. The upper portion of the barrel which contains the plunger and the first valve has a side-pipe branching off, as represented in the figure below, having at a short distance from its origin the second valve, both valves opening upward. Now if the plunger be depressed to the lower valve, and then raised, that will open, while the valve in the lateral pipe remains closed, and the pressure of the atmosphere on the water in the well will cause it to rise a little and expel a part of the air through the first valve; the piston then being lowered that valve will close, and the air above it be expelled through the other valve; thus every elevation of the piston will make the water rise higher in the cylinder till it has expelled all the air, and it will consequently at the next lifting of the piston, pass above the first valve, and the piston being again lowered, as the liquid cannot descend, the valve being closed, it will be forced into the lateral pipe, through its valve, and as it is prevented from returning again by that valve, it will continue to ascend with every downward stroke of the piston, and may thus be raised to any height required.

Fig. 92.



2. In the forcing-pump the stream would be intermitting were it not for the upper part of the side-pipe containing a portion of

* The subject of atmospheric pressure will be explained in the chapter on Pneumatics.

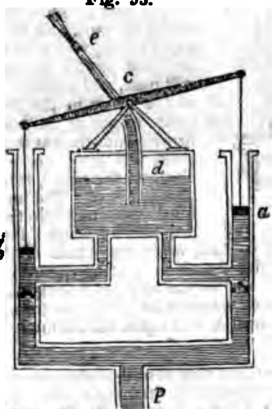
CXLIV. What is the extent of the column of liquid raised? Give the illustration.
CXLV. Describe the forcing-pump? Give the first illustration. What is the second illustration of the forcing-pump.

confined air, and hence called the *air-chamber*. This air, being compressed by the action of the plunger raising the column of water against it, reacts by its own elastic force upon the surface of the liquid and forces it up the narrow tube, and thus keeps up an equable stream.

CXLVI. The common fire-engine is merely a double forcing-pump so contrived as to throw a continued stream of water.

Illustration. It consists essentially of two barrels *a* & *b*, fig. 93, in which two pistons move perpendicularly being attached to the ends of working beam *c*. *d* is an air-chamber, the air by its elasticity, pressing upon the column of liquid steadily forces it through the pipe *e*. The water entering by the pipe *p*, passes up the two barrels through the valves placed a little below the pistons, and thence into the air-chamber *d*, when it is forced out through the pipe *e*.

Fig. 93.



CXLVII. The fourth kind of engine for raising water is that which acts either by the gravity of a portion of the water to be raised, or by centrifugal force. This includes the *fountain of Hero*, the *centrifugal pump*, and the *Belier Hydraulique or hydraulic ram of Montgolfier*.

CXLVIII. The fountain of Hero or Hungarian pump produces its effect by a confined portion of air, and the pressure upon it of a high column of water.

CXLVI. Describe the fire engine? CLXVII. What is the fourth kind of engine used for raising water. CXLVIII. Describe the fountain of Hero.

Fig. 94.

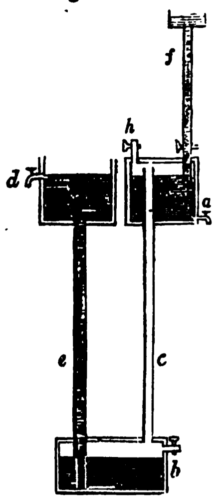


Illustration. Its construction will be understood by fig. 94, but its form may be varied according to the fancy or taste. The boxes *a* and *b*, together with the two tubes *c e*, are made air-tight, and strong, in proportion to the height it is desired the water should rise. To set the machine in action nothing more is necessary than to shut the cocks *a* and *f*, and open the cock *h*, from which the air previously contained in the lower chest will escape, and its place will be filled up by the water below, which will pass through the valve contained in the bottom of lower box and opening upward until the chest *b*, is completely filled. That done, the air-cock *h*, is to be shut, and the water-cock *f*, opened, when a column of water, equal to the full height and pressure of the cistern *f*, will rush down the pipe, and by filling the chest *a*, will expel its air, which has no other opportunity of escaping but by the open pipe *c*, down which it will pass, and produce a pressure on the surface of the water in the lower chest, equal to the entire height of the column *f*, and the air thus thrown into the chest *b*, being in a condensed state, will force the water previously in that chest up the pipe *e*, from whence it will be discharged at *d*. The lower chest *b*, will now be filled with air, while the upper chest *a*, will be occupied by water: therefore, the cock *f*, must be shut, and that at *a* opened, when the whole of the water from *a* will be discharged, and will give the air in *b*, an opportunity of returning again into *a* through the pipe, *c*; and as the air from *b* escapes, its place will be occupied by a new charge of water, which will rise through the valve, contained in the bottom of the chest *b*, and again fill the lower chest, and prepare it for a second discharge.

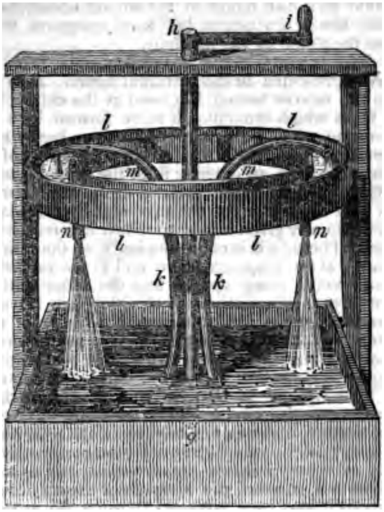
Observation. The machine now described was called the Hungarian machine, because it was once employed in draining a mine at Chemnitz in Hungary; the force with which it acts depends on the relative length of the pipes *e f* and *c*, and at the mines above mentioned a curious and surprising phenomenon takes place on opening the stop-cock *h*, after having forced all the water from the box *b*: the water and air will rush out at *h*, with great violence and the drops of water by the great cold produced from the sudden expansion of the air are instantly converted to hail or lumps of ice, issuing with such violence as to pierce a card of thick pasteboard like a pistol-ball.

CXLIX. *The centrifugal pump* is a machine constructed to raise water by means of the centrifugal power.

Illustration. It has several different forms, one of the most simple of which is shown at fig. 95, in which *g h* represent an upright spindle, so fixed, that rapid rotatory motion may be communicated to it by the winch *i*, and *k m*

What is the observation on this machine? What is the centrifugal pump.

Fig. 95.



represent any number of curved pipes (each of which contains one valve opening upward) so disposed and fixed to the spindle, that their lowest ends may be near to it, and be covered by the water to be raised; and their upper ends, which are quite open, are extended to a considerable distance from the centre of motion, and finally bent downward to prevent the dispersion of the water. The several curved pipes must be filled with water, which will be retained in them by their bottom valves, and are then put into rapid motion by turning the winch, when the higher ends *m m*, of the pipe will describe a much larger circle than the ends below, and consequently such a centrifugal force, or tendency to fly off and empty the pipes, will be induced at the upper ends as will produce a vacuum, capable of raising a column of water. *l l l l*, is a circular pan or reservoir to receive the upper ends of all the pipes and the water they deliver, which runs off by spouts at *n n*. This machine, according to theory, should deliver water with a velocity nearly equal to that with which the upper ends of the pipes move, but in practice it has failed of producing very advantageous effects.

CL. The *Belier Hydraulique* or *Hydraulic Ram* is a machine to raise water by means of the momentum of a current of water suddenly stopped in its course, and made to act in another direction.

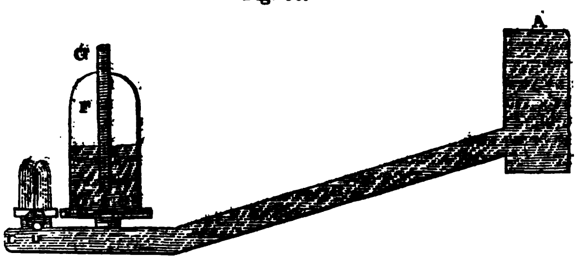
CLIX. What is the centrifugal pump? Describe it. CL. What is the Belier Hydraulique?

Observation. As this machine produces a kind of intermitting motion from the alternate flux and reflux of the stream accompanied with a noise arising from the shock, its action has been compared to the butting of a ram; and hence the name of the machine.

Description. The essential parts of the hydraulic ram, as exhibited by Montgolfier are represented in the marginal figure. A, is a head of water, connected with the tube or tunnel B, closed at the extremity C, but having an aperture at D, to which is adapted a valve formed by a ball of porcelain or copper, hollow, so as to be not more than as heavy again as an equal volume of water, and supported near the orifice by a sort of muzzle or cage. F, is a reservoir of air, with an opening from the tunnel B, and a valve E, fitted to it, but lifting upward, and prevented from displacement by a muzzle over it. From near the bottom of the air-vessel F proceeds a pipe G, which may be continued to any given height to which it is requisite that the water should be raised. The tube B is called the body of the ram; the tube G the tube of ascension; D the stoppage valve, and E the ascension valve.

Now the former valve being opened and the latter shut when the water begins to run, it at first escapes through the stoppage valve D, but soon acquiring a momentum, from the accelerating velocity of its fall, it drives the ball D against the opening and stops the passage in that direction; the reflected stream then strikes up the valve E, and water enters into the air-vessel F, through the ascension valve: the ball D, as soon as it is relieved from pressure, falls into its muzzle, and makes way for the water again to escape through the stoppage valve, while the other valve closes through its weight and the reaction of the compressed air in the reservoir. The renewed momentum of the stream presently shuts the stoppage valve, and lifting the ascension valve, more water enters the air-vessel, and as soon as the orifice of the pipe G becomes covered, the pressure of the air drives the water upward; for that which has been admitted through the ascension valve cannot return, and more being added at each stroke of the engine, it may be gradually raised to an indefinite height.

Fig. 96.



CLI. The third general division of the subject of Hydraulics includes those machines or engines used for communicating motion by means of water which is the power; such as water-wheels.

What is the observation? Give the description. CLI. What is the third general division of hydraulics.

XLVI. Water-wheels are divided into three classes; the undershot, over-shot, and breast wheel. The under-shot-wheel is said to be of earlier origin than the others; and it is likewise the most common.

Fig. 97.

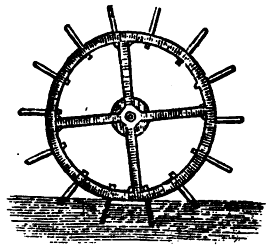
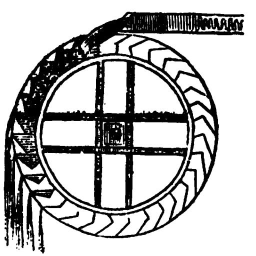


Illustration. It consists, as is shown in the above figure, of a wheel on the periphery of which are fixed a number of flat boards at equal distances, and set at right angles to the plane of the wheel. They are called float-boards; and the wheel is so placed that for its lowest point is immersed in flowing water, and is set in motion by the impact of the water on the boards as they successively dip into it. As a wheel of this kind will revolve in any stream which furnishes a current of sufficient power, it may be used where the descent of the water is by far too trifling to turn a breast-wheel, much less an overshot-wheel.

CLIII. The overshot-waterwheel, takes its name from the fact that, the water shoots over it, and acts by its weight as well as the force of the current in turning the wheel.

Fig. 98.



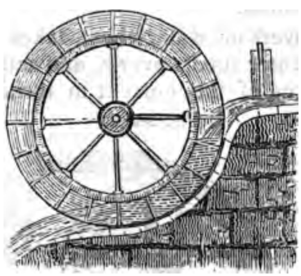
CLII. Into how many classes are water-wheels divided? What name is given to that part of an undershot-wheel which receives the impact of the water? In what situations is the peculiar advantage of this kind of wheel to be obtained? CLIII. Describe the overshot-wheel.

Illustration. This kind of wheel, as may be conceived from the preceding figure, can only be used where a considerable fall of water can be obtained. On its periphery are fixed a number of cavities called buckets, being closed on both sides, but having openings, so that the water, conducted by a level trough of the same breadth with the wheel, may fill each bucket in succession, as it reaches that point in the circuit of the wheel at which the weight of the water can begin to act on its circumference. From the peculiar form of the buckets they retain the water partially till they have descended to near the lowest point of the circuit, and having discharged their contents into the tail-stream, they ascend on the opposite side to be filled as before. As the overshot-wheel requires the greatest fall of water to make it act, so is it likewise the most powerful with reference to the effect produced, by the momentum of flowing water.

CLIV. The breast-wheel is one in which the water falls upon its float-boards, about on a horizontal level with the axle or shaft of the wheel; it is therefore a sort of machine having an intermediate character compared with the undershot and overshot-wheel.

Illustration. It has float-boards like the former, but they are converted into buckets somewhat after the manner of those in the chain-pump, as they move in a cavity adapted to the circumference of the wheel, as shown in the cut below. The water passes through this cavity, entering it nearly on a level with the axis of the wheel. In this case the liquid acts chiefly by its weight: and the machine, though less efficient than the overshot-wheel, is more so than the other. It is, therefore, only used where the fall of water happens to be peculiarly adapted for the purpose.

Fig. 99.



CLV. The machine called Barker's mill is constructed on what is called the principle of reaction of water, and was invented by Dr. Barker in the 17th century.

Description 1. It consists of a hollow cylinder *a*, (fig. 100,) enlarged at top into a funnel *b*, into which water is discharged by the tube *b*, and pass-

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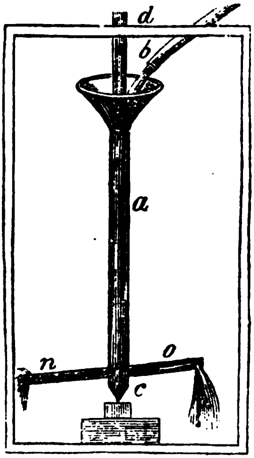
CLIV. Describe the breast-wheel. CLV. Describe Barker's mill.

Fig. 100.



›wn the cylinder escapes through the small apertures *n* & *o*, near tremities of the arm; the apertures being on opposite sides of the

'o start this machine nothing more is necessary than to fill it with by the tube *b*, the spouting streams will communicate rotary motion vertical cylinder. The action depends not on the pressure of the against the atmosphere, as sometimes stated, but on the hydrostatic re of the column of water in the cylinder *a*, which exerts great force, interior of the hollow arms *n* & *o*, and that force beir g removed from nts whenever the water spouts but not from the corresponding points :e to the apertures, hence the pressure on those points causes the ma- o rotate in a direction opposite to that in which the spouting cur- ıoves. It may be easily attached to, and made to turn other ma- r.

PNEUMATICS.

LVI. The science of pneumatics treats of the *weight*, ·ure, *density*, *elasticity*, and *compressibility* of the sphere.

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is it set in motion, and what is the principle on which it acts? CLVI. De- ıeumatics.

CLVII. By the atmosphere we mean that aerial or gaseous fluid which every where covers the surface of the earth to a depth of forty or fifty miles, and which is known under the names of *air*, *common air*, *the atmosphere*, &c.

CLVIII. The distinction between liquids and those more elastic fluids called air, gas, vapour, or steam, depends, it is believed, chiefly or entirely on occasional causes, and especially on the temperature and pressure to which they are subjected.

Illustration 1. Thus water is a liquid when exposed to the ordinary temperature of our atmosphere, but if heated until it boils it becomes an elastic fluid like air.

2. Fixed air, or carbonic acid, when exposed to the pressure of the atmosphere is a gaseous fluid, but when put into a close vessel and pressed with a force of 600 pounds on every square inch of the vessel it becomes a transparent liquid. It is believed indeed that all the gaseous bodies could be liquefied either by great cold or pressure, or by both combined.

CLVIX. The atmosphere is essentially composed of two simple gases called *oxygen* and *nitrogen;* by measure, 100 parts contain about 20 of oxygen, and 80 of nitrogen.

Observation 1. This atmosphere is necessary to animal and vegetable life, and to combustion; it is a very heterogeneous mixture, being filled with various kinds of vapours.

2. The height to which the atmosphere extends has never been exactly ascertained; but at a greater height than 45 miles, it ceases to reflect the rays of light from the sun.

CLX. The air is not visible, because it is perfectly transparent: but it may be perceived on moving the hand in it.

Example 1. The existence of the air may be ascertained by swinging the hand edgewise swiftly up and down, which gives the idea of separating the parts of some resisting medium.

2. Any swift motion, as of a stick, or whip, or fan, proves the existence of air as a resisting medium.

CLXI. Air is 815 times lighter than water, and 11065 times lighter than quicksilver, but the whole atmosphere presses on all sides like other fluids, upon whatever is immersed in it, and in proportion to the depths.

CLVII. Define the atmosphere. CLVIII. What is the distinction between liquids and elastic fluids? Illustrate by water, also by carbonic acid. CLIX. What is the composition and proportions of the atmosphere? What are the observations? CLX. How is the pressure of air ascertained. CLXI. What is the weight of air and how does it press?

Example 1. It is well known that the pressure of the air is less upon a high mountain than upon a plain or valley. It is on this principle that people complain of shortness of breath, giddiness and a sense of oppression on ascending a very high mountain as Mont Blanc, Chimborazo, &c. Here the air is so rarefied that the pressure of the blood and other fluids in the body, is greater than that of the air without, and produces the unpleasant sensations above named. Baron Humboldt, on ascending point Chimborazo, found that the blood was forced through the pores of the skin, and that breathing became exceedingly difficult, compelling him to return immediately to the lower regions, where the superior pressure of the external air was sufficient to counteract that of the fluids within the body.

2. The pressure of the air may be thus shown: cover a wineglass completely filled with water, by a piece of writing paper; then place the palm of the hand over the paper, so as to hold it tight and accurately even. The glass may then be turned upside down, and the hand removed without the water running out. The pressure of the air upon the paper sustains the weight of the water.

3. It is the pressure of the atmosphere which sustains the mercury in the barometer tube.

On the surface of the earth the water boils at 212 degrees; on Mont Blanc which is fifteen thousand feet high, it boils at 187 degrees. These and many other experiments show, the higher we ascend from the surface of the earth, the less is the atmospheric pressure.

CLXII. The air can be compressed into a less space than it naturally occupies.

Experiment 1. Take a glass tube open only at one end, and it is of course full of air. Plunge the open end into a bowl of water and the liquid will rise to a small height in the tube, showing that the air is compressed into a smaller space than it naturally occupies by the upward pressure of the water.

2. Let a small cork be placed on the surface of the water, within the inverted tube used in the last experiment; the situation of the cork will show the height of the liquid within the tube and consequently how much the air has been compressed.

3. On this principle the *diving-bell* is constructed, by which persons are enabled to descend into the depths of the ocean, and recover valuable articles lost from the wreck of vessels and other accidental causes.

THE DIVING-BELL.

The diving-bell consists of a heavy vessel in the form of a bell with the mouth downward and generally constructed of cast iron or of wood, the latter loaded with weights to make it sink. It is usually furnished with shelves and seats on the sides for the convenience of those who descend in it; and several strong glass lenses are fitted into the upper part for the admission of light. There is likewise a stop-cock, by opening which the air, rendered impure by respiration, may from time to time be discharged and rise in bubbles to the surface of the water; and provision must be made for the regular supply of fresh air, which may be sent down through pipes from one or more large condensing syringes, worked on the deck of a vessel above or by the person in the bell. The bell must be properly suspended

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Give the examples. CLXII. Is air compressible? What experiment to prove it? What experiment with a cork? Describe the diving-bell.

from a crane, or cross-beam, furnished with tackles of pulleys, that it may be lowered, raised, or otherwise moved, according to circumstances.

4. Some interesting experiments were made a few years since on the English frigate Huzzah, sunk at Hell-Gate, between the city of New York and Long Island sound in about eighty feet of water; the vessel was sunk during the Revolutionary war. A great variety of articles were obtained by means of the diving-bell.

5. Some curious inventions, for the purpose of submarine navigation, have been invented in the United States. Robert Fulton, the successful inventor of the steamboat, contrived a machine of this kind, called a Torpedo; and David Bushnell invented a submarine vessel in which a man might pass a considerable distance under water; and by means of this, and its accompanying magazine of artillery, an attempt was made to blow up a British vessel in the harbour of New York, during the late war with England.* This project appears to have failed merely from the difficulty or rather impossibility of attaching the magazine to the bottom of the ship, which was attempted by means of a sharp iron screw, which passed out from the top of the diving-machine, and communicated with the inside by a water-joint, being provided with a crank at its lower end, by which the engineer was to drive it into the ship's bottom. The machine affording no fixed point to act from, the power applied to the screw could make no impression on the ship; and thus this bold adventure was disconcerted.

CLXIII. The air is of an elastic or expanding nature, and the force of the spring is equal to what is commonly called its weight. The spring, however, operates in all directions, and is as powerful in small as large bulks.

Definition. When a substance is either compressed into a smaller bulk, as happens on sitting down upon a well-stuffed cushion, or extended, as on pulling a piece of India rubber, and after the pressure in the one case, and the extending force in the other, the cushion and the rubber bound back to their previous state, they are said to possess elasticity. Of this property I shall give a few illustrations, without, for the present, inquiring into the cause.

Experiment 1. Fill a bladder with air by blowing into it, and in this state the bladder is highly elastic; it proves also that air is as much a substance as wood or metal, for no force can, without breaking the bladder, bring the sides together, though the parts of an empty bladder may be squeezed into any shape.

2. Open a pair of common bellows in the usual manner, and then stop the muzzle securely, and no force can bring the parts together, without first unstopping the muzzle, or bursting the leather, another proof that air is an impervious substance.

CLXIV. Wind is air in motion, and its force is according to the velocity with which it moves.

* For a description of this curious engine, see a paper on "Submarine Navigation," by Charles Griswold, in the American Journal of Science, vol. ii. p. 94.

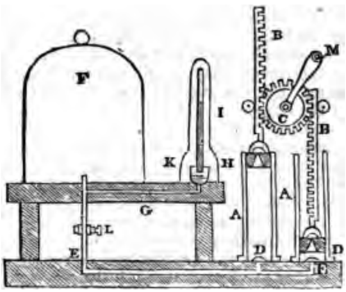
What experiments on the frigate Huzzah? Describe the method of Bushnell for blowing up an enemy's ships. Why did this plan prove unsuccessful? CLXIII. What is said of the nature of the air? Give the definition and the experiments 1 and 2. CLXIV. What is Wind?

ervation. As fishes are surrounded by water, and live and move in that so are we, and all other land animals, surrounded by air, and live and in it. A fish which is taken out of the water, will die in a short time; human being, or any other animal taken out of the aerial fluid, will in il die much sooner.

the progressive motion of water from one place to another, is called a *ıt* of water; so the progressive motion of the atmospherical air is call- general *wind*, which, according to the different velocities of that fluid, e particularly specified by the appellations, *breeze*, *gentle wind*, *gale*, *ane*, &c.

LXV. Air-pumps are machines constructed for the ose of exhausting the air from close vessels, generally d receivers

Fig. 101.



stration. The above figure exhibits a section of an air-pump, from it may be perceived that it essentially consists of two exhausting syr- so arranged that they can be worked alternately. The syringes are d A A, and their pistons are moved up and down within the barrels, racks or toothed rods B B, adapted to corresponding teeth on the peri- of the wheel C, having a winch or handle M, by which it may be l so as to raise and depress either piston successively. Each of the pis- furnished with a valve by which the air escapes as the piston descends, iere are other valves D D, at the bottom of each barrel, which become l by either piston in its descent, but when it is drawn up, open a passage he tube E E, communicating with the cavity of the glass bell F, called iver. From the tube E passes off another tube G, the extremity of ı opens into the bell-shaped tube K, within which is a small basin H, ining mercury, and the small tube I, closed at the upper end only, has wer end plunged beneath the surface of the mercury. At L is a stop- which when closed cuts off the communication between the receiver he syringes, and which must therefore be opened while the machine is action. Another stop-cock, not shown in the figure, closes a passage gh which the external air may be admitted under the receiver, when the of an experiment has been ascertained.

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at observations to illustrate it? CLXV. Describe the air-pump.

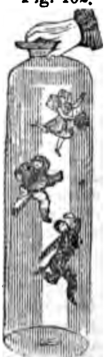
CLXVI. The elastic force of air is shown in the following experiment :—

Experiment 1. Place under the receiver of an air-pump a bladder, which has been about half filled with air and firmly tied at the neck so as to prevent it from escaping; on exhuasting the receiver gradually, the bladder will be seen to swell, from the expansion of the air within it; and if the exhaustion be continued long enough, the bladder will burst, from the elastic force of the air it contained, no longer counterbalanced by pressure on the external surface.

2. A square or flat glass vial, filled with air, well corked and fastened with wire, if placed under the receiver, will crack from the expansion of the air within it; as soon as the pressure is withdrawn from its surface by the exhaustion of the receiver. A vial of the usual shape would resist force applied internally or externally, much better than one with flat sides, in consequence of its arched figure; hence the globular or hemispherical shape of the receiver, renders it best adapted for its purpose.

3. Shrivelled apples, prunes, or raisins, with their skins unbroken, when placed under a receiver, on the air being exhausted, will become plump from the elasticity of the air included in those fruits; and thus a bunch of dried raisins may be made to assume the appearance of a fine cluster of grapes, and a similar apparent renovation may be effected on the apples and prunes; but on readmitting the air into the receiver the fruits would all resume the wrinkles which betray their age.

Fig. 102.



4. If a large glass globe with an open mouth have a piece of bladder tied over it, so securely that the air within it cannot escape while the bladder remains whole, and it be set under a receiver, while the air is being withdrawn from it, that within the globe will expand by its elastic force, and raise the bladder to a convex shape, distending it more and more as the exhaustion increases, till at length the bladder will be ruptured, and the air in the globe will expand itself through the receiver.

5. A very amusing exhibition of the effect produced by the elasticity of the air may be made by means of the apparatus represented in the margin. Hollow glass figures, about an inch and a half in length, resembling men or women, must be procured, each having a hole in one foot, and the glass must be of such thickness that the figures will float near the surface of water when they are filled with common air. They are then to be immersed in a tall glass jar nearly filled with water, and covered on the top with a strong bladder, fastened air-tight. If the bladder now be pressed inwards with the finger, the water being almost *incompressible*, and the air quite the reverse, that contained in the little images will yield to the compressing force, and becoming contracted, water will enter, and the images thus becoming specifically heavier than they were at first will descend towards the bottom of the jar; on the pressure above being removed, the air in each image recovering its elastic force, will expel the water, and the images will rise as before. By forcing a little

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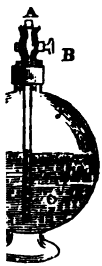
How is the elasticity of the air proved by the experiment of the flaccid bladder? What will occur when a thin flat or square vial is placed under a receiver, and the air exhausted while the vial remains corked? How may shrivelled fruit be temporarily restored to a plump appearance? Explain the experiment of the *glass globe and bladder*. Describe the pneumatic toy called the bottle of imps. In what manner may the imps be made to rise from the bottom of water, and how is the experiment to be explained?

lto one or two of the figures before they are placed in the jar, they
sily be made to float at different heights; and thus their motions
greatly varied, by regulating the pressure on the bladder. These
ıges are called the bottle of *imps*.

e effect of air acting by its elastic force on the surface of water may
usly exhibited in the formation of *jets d'eau*, or spouting fountains.
rong decanter be filled to about half its height with water, and a
be of small bore be passed into it nearly to the bottom, and fixed
, going through a hole drilled in a cork, with a piece of bladder tied
and round the tube. This bottle is then to be placed under a tall re-
n the plate of an air-pump; and on the receiver being exhausted,
within the bottle will expand, and pressing on the surface of the
ause it to issue from the top of the tube in a jet, the height of which
roportioned to the degree of rarefaction of the air under the receiver.

. 103.



7. Compressed air may be made to produce a simi-lar effect, which may be thus displayed: a strong bottle somewhat more than half filled with water, as represented in the marginal figure, by the line D E, must have a tube A C fitting into its neck, and capable of being opened or closed at pleasure, by turning the stop-cock B. A condensing syringe being adapted to the tube at A, and the stop-cock opened, air is to be forced into the bottle, which rising through the water, will by its density press strongly on the surface of that liquid; then after turning the stop-cock the syringe is to be removed, and a small jet-pipe being fitted to the tube A, the stop-cock is to be opened, and the elasticity of the condensed air in the bottle will drive up the liquid in a jet, the height of which will gradually diminish, as the included air, by its expansion, ap-
s nearer and nearer to the density of the external air.

mall vial with a well-fitted cork, having a little tube or a stem of a
pipe passed through it, and reaching nearly to the bottom of the
tly filled with water, will on blowing strongly into the bottle through
, exhibit effects precisely analogous to those of the apparatus just
d.

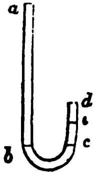
rce a hole in the small end of an egg, and with this part downward
e egg under the receiver of the air-pump, and exhaust—the expansion
ıbble of air contained in the large end will force the contents from

common experiment among boys is made on the same principle.
piece of thick spongy sole-leather, cut it into a circular form, and
the centre pass a string; wet it thoroughly, and place it flat on a
surface; then try to pull it up in a perpendicular direction. A vacuum is
n the centre, while the edges are pressed down by the weight of the
ere. In this way a smooth stone of many pounds weight may be

ot of the common house-fly is formed in the same manner which
t to walk with ease upon the walls and ceilings of our rooms.
he elastic force as well as the compressibility of air is illustrated in
wing experiment:—

. the construction of the *Jet d'eau*. How is the force of air applied in the
ed air fountain? Explain the experiment with the egg. What is the ex-
with the spongy leather?

Fig. 104.



This bent tube $a\ b\ c\ d$, fig. 104, is open at both ends. I have poured mercury into the tube so as to rise in both sides of the tube c and b; the part from $c\ d$, is full of air at the common density; I stop up d, so as to make it air-tight, and pour mercury into a so that the column of mercury ab, shall be equal in length to the height at which it stands in the barometer at the time. The air in the shorter leg will now be compressed by the weight of the atmosphere, and also with an additional equal weight of a column of mercury; and the mercury in the shorter leg will be risen to e, and $c\ e$, is only the half of $d\ c$; that is, the pressure of a double atmosphere compresses the air to half the space which it naturally occupies. If another equal column of mercury, were added to the length $a\ b$, the air in $d\ c$, would be reduced into one fourth the space that it formerly occupied.

12. Set a cup of water in the exhausted receiver of an air-pump, and when the air is nearly exhausted from the receiver, the water will have all the appearance of boiling, in consequence of the expansion of the air and its rising out of the water.

13. Beer a little warmed, will from the same cause, whilst the internal air is being exhausted, have the appearance of boiling.—Thus it may be shown that air is contained in water, animals and vegetables.

14. To a cylindrical piece of wood, fasten a small piece of lead, so as to make it specifically heavier than water, and place it in a vessel of water under a receiver; upon exhausting the air the wood will swim; some particles of air escaping from the wood and thereby diminishing its specific gravity.

CLXVII. The air presses upon the surface of the earth, and upon all other bodies about it with a force of about 14 1-2 pounds on every square inch of surface.

Observation 1. A man of ordinary stature will hence be loaded with a weight of about forty thousand pounds: we do not feel inconvenienced from it for a reason before stated, namely the fluids within the body press outward and counteract the pressure of the atmosphere. A fish in the deep sea sustains a still greater pressure without inconvenience.

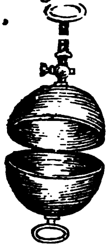
2. The pressure of the air on the body is strikingly proved by partially removing it. Let one of the fingers for example, be pushed to the bottom of a thimble and withdrawn so as to expel all the air and to readmit little or none, when it will be found to press on the tip of the finger, so as to be even painful. In the surgical operation of cupping, the air is driven out from under the cupping-glass by the flame of a spirit-of-wine-lamp, and every body who has experienced the operation must recollect well the painful pressure of the glass forced on the skin by the surrounding air.

3. The most celebrated experiments of this kind were made by Galileo, Torricelli, Pascal, and Otto Guericke. Galileo discovered that a pump would not draw water at a greater depth than about thirty-two feet—the alleged limit of Nature's aborrence of a vacuity, to which it was in these days absurdly ascribed, instead of the true cause, the pressure of the air.

What experiment with the bent glass tube? What experiment with a cup of water? What experiment with beer? What experiment with a cylinder of wood? CLXVII. What is the amount of the pressure of the air? What pressure does an ordinary man sustain? What remarks on the thimble and cupping-glass? What celebrated experiments are referred to?

Torricelli's ingenious substitution of quicksilver for water in the experiment, led to the invention of an instrument called the *Barometer*, for estimating the atmospheric pressure, and Pascal verified the correctness of the explanation by performing the experiment on the lofty summit of the Puy de Dome in Auvergne, where of course the air was found to press lighter than in the valley below. Even now, this very experiment is daily made for ascertaining the heights of accessible mountains, as well as for indicating changes of the weather.

Fig. 105.



4. A more exact estimate of the weight of the atmosphere may be formed by attending to the result of an experiment to show its effect on the surface of two hollow hemispheres, from which the air has been extracted by means of an air-pump or exhausting syringe. These hemispheres, constructed of brass, should be furnished with handles, or hooks, by means of which they may be suspended; one of which may be fixed, but the other should be movable. In the tubular neck to which this handle is screwed is a stop-cock, which being opened, and the handle removed, the hemisphere is to be screwed on the pump-plate, or on to an exhausting syringe; and the other hemisphere having been fitted to it, a vacuum is to be formed in the interior by working the pump. The stop-cock must then be turned so as to prevent the re-entrance of air, and on unscrewing the brass globe, and refixing the handle, it will be found that the hemispheres composing it are firmly united by the pressure of the external air. Suppose the diameter of the globe to be six inches, the surface of a section through the centre would be about twenty-eight inches square; and hence the pressure of the air upon one square inch being known, the force requisite to separate the hemispheres, supposing the exhaustion to be nearly complete, might easily be computed.

5. This is usually termed the Magdeburg experiment, it having been originally contrived by Otto Guericke, of Magdeburg, the inventor of the air-pump; and it appears to have led him to that important discovery. For the manner in which he originally conducted the experiment was by filling the space included between the hemispheres, when pressed together, with water to expel the air, and then pumping out the water, while the air was prevented from re-entering by turning a stop-cock. Having thus ascertained the fact of the existence of atmospheric pressure to a great degree, he proceeded to the invention of the air-pump, by means of which the exhaustion of the joined hemispheres could be much more readily and conveniently effected than by the operose process he had at first adopted. This ingenious philosopher operated with two copper hemispheres, nearly a Magdeburg ell in diameter; and the amount of pressure on such an extent of surface was so great, that when the interior cavity had been exhausted, the separation of the hemispheres could not be effected by the strength of twenty-four horses, twelve being harnessed together on each side, and dragging in opposite directions.

CLXVIII. If a glass tube thirty-one inches long having one end closed, be filled with quicksilver, and have its open end immersed in a basin of the same liquid, the quicksilver will sink down to about 28 or 29 inches in

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What is the Barometer? Describe the illustrations 4 and 5.

the closed end of the tube, leaving an empty space of two or three inches which space is called a vacuum and the instrument is called a *barometer.*

Illustration 1. In the wood-cut below is represented the experiment above-mentioned; the right hand tube A B, is to be filled with quicksilver and inverted in the vessel C D, when the liquid sinks down a few inches to E; this height at which the fluid stands will vary with the state of the weather, and thus becomes an indication of changes in the weather, and as the pressure of the atmosphere on the surface of the liquid F, supports the column and keeps it up near E, it is shown that the weight of the atmosphere is variable.

Fig. 106.

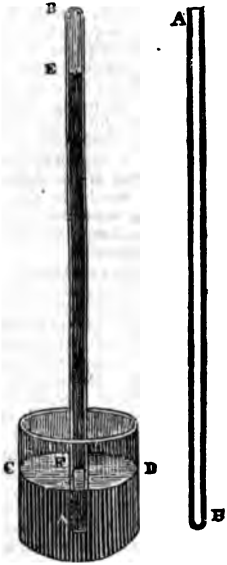
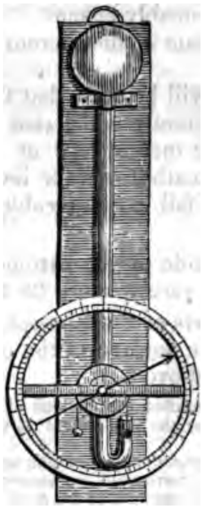


Illustration 2. One of the most common of these instruments for domestic use, is made with a glass tube having a round hollow ball at top, and a bend at the bottom; this end of the tube being left open. The tube is filled with quicksilver, carefully freed from air, and into the open end is hung a glass float from a string, with a weight attached, passing over a pulley to which is attached a hand that turns as the quicksilver rises or sinks by changes in the pressure of the air, indicating changes of weather.

Illustrate the construction of the barometer.

Fig. 107.



Common-wheel barometer, with the frontcase removed to show the mechanism.

CLXIX. The use of the barometer is somewhat limited; and it is difficult to give any accurate rules as to the indicatious of the instrument: the following have been taken from the Library of Useful Knowledge :—

1. *Generally*, the rising of the mercury indicates the approach of fair weather; the falling of it that of foul weather.

2. In hot weather the fall indicates thunder.

3. In winter the rise indicates frost, and in frost the fall indicates thaw, and the rise, snow.

4. If fair or foul weather *immediately* follows the rise or fall, little of it is to be expected.

5. If fair or foul weather continue for some days, while

Describe the *wheel barometer*. CLXIX. What is said of the uses of the barometer? Repeat the several rules laid down for calculating the changes of weather by the barometer.

the mercury is falling or rising, a continuance of the contrary weather will probably ensue.

6. An unsettled state of the mercury indicates changeable weather.

By these rules it will be seen that the words engraved on the plate are frequently calculated to mislead the observer. Thus, if the mercury be at *much rain* and rise to *changeable*, fair weather is to be looked for. Again, if it be at *set fair*, and fall to changeable, foul weather may be expected.

CLXX. The altitude of the barometer varies from 28 to 31 inches, but it is rarely below 28 1-2 or above 30 1-2.

CLXXI. As all parts of the atmosphere press upon each other, the air near the surface of the earth, is denser than that at some height above it.

Observation 1. It is computed that the air at seven miles high is one quarter as dense as it is at the surface; at 14 miles one sixteenth; at 21 miles one sixty-fourth, &c.

2. On this principle the heights of mountains are calculated by means of the barometer, but so many corrections are necessary that the results are to be considered as only approximations to the truth.

CLXXII. The elastic force of air is finely illustrated in the instrument denominated the *air-gun;* which consists of a barrel like that of a common gun, and a hollow metallic ball near the breech, into which is condensed by means of a forcing-pump a large quantity of air. This air being discharged in small quantities at a time, into the breech behind the ball, forces it forward with great velocity.

Observation 1. It is somewhat remarkable that this instrument should have been in use before the discovery of the air-pump or barometer. It appears to have been known in the time of Louis XIII. of France.

2. From what has been already stated on the density and elasticity of air, it will follow that all bodies on the surface of the earth sustain a pressure from the superincumbent atmosphere equal to the weight of a column of water, about 34 feet in height, with a base corresponding in extent to that of the body or bodies pressed upon. This pressure may be estimated at from 14 to 15 pounds on every square inch of surface, being the weight of a col-

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CLXX. What is the altitude of the barometer? CLXXI. Where is the air densest? What is the rate of diminution of the density of the air as we ascend? What is said of calculating the heights of mountains? CLXXII. Describe the air-gun. What is said of the history of the air-gun? What weight do bodies on the surface of the earth sustain?

umn of mercury 30 inches high, and 1 inch square at the base; hence a column of water 34 feet high, a column of quicksilver 30 inches, and a column of air 45 miles high, will each weigh the same, that is, about 15 pounds.

3. Some idea of the weight of the whole atmosphere, encompassing the earth on every side, may be formed from a calculation which has been made to determine what must be the diameter of a sphere of lead, the weight of which would be equal to that of the entire atmosphere; and from which it appears that the sphere must have a diameter nearly 60 miles in length; which would correspond in weight with a mass of water sufficient to cover the whole surface of the earth to the height of 34 feet.

CLXXIII. Aerostatics, or the art of navigating the atmosphere, depends on the specific gravity of different gases or of the same gas at different temperatures.

CLXXIV. The common, or air-balloon ascends by being filled with a gas or air lighter than the same bulk of atmosphere.

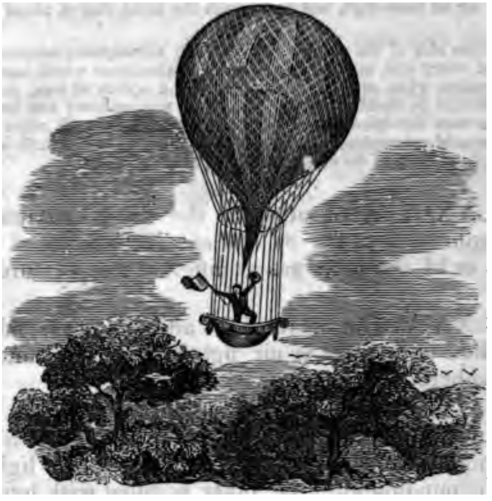
CLXXV. Balloons are of two kinds—one, filled with common air rarefied by heat, and thus made lighter than the surrounding air: the other is filled with hydrogen, a gas nearly fifteen times lighter than air; the latter is the only one in general use.

Observation 1. The balloon was invented by Montgolfier a French paper manufacturer, in 1782-3, who first filled a paper bag with heated air and let it pass up through the chimney; afterward the balloons were made of varnished silk with the mouth open, and directed downward and a light wire grate, filled with combustibles lighted and suspended at a little distance below. The air within the balloon rarefied by the heat becomes much lighter than the same bulk without, and causes the balloon to ascend with considerable velocity; such balloons are frequently constructed at the present day by boys.

2. Balloons filled with hydrogen are frequently sent up of a sufficient size to carry up two or three persons at a time. An ascension was made from Paris in 1804 to the height of twenty-three thousand feet, the greatest height to which man has yet penetrated by means of balloons. The following wood-cut illustrates the form and general appearance of modern balloons with the manner of suspending the car, &c.

What is the computed weight of the whole atmosphere? CLXXIII. Define Aerostatics. CLXXIV. Describe the principle of the balloon. CLXXV. What the kinds of balloons in use? What is the observation on the history of balloons? Describe observation 2.

Fig. 108.



CLXXVI. One of the most interesting of the school amusements is the exercise of the paper-kite.

Fig. 109.

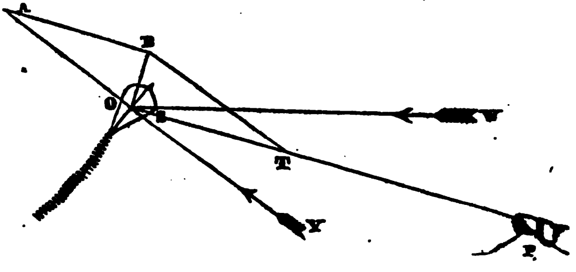


Illustration 1. It was by means of this machine, says Prof. Johnson of Philadelphia, that Dr. Franklin demonstrated the identity of lightning with the electric fluid. The paper-kite has been employed to convey a line to the

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CLXXVI. What is said of the paper kite, and to what useful purposes has it been applied?

shore from a vessel wrecked on a rocky coast; and a few years ago, a Mr. Pocock, of London, made repeated experiments, by means of which he ascertained the possibility of travelling in a carriage drawn by two paper-kites, supported at a moderate elevation, and impelled by the wind. The elevation of the paper-kite in the usual manner, with a line attached to a loop on the under side of the machine, is satisfactorily elucidated by Dr. Paris, who has shown that the ascent of the kite affords an example of the composition of forces, the mode of action of which is exhibited in fig. 109, on page 102.

2. The kite is here represented rising from the ground, the line W denoting the direction and force of the wind, which falling on an oblique surface, will be resolved into two forces, namely, one parallel with it, and another perpendicular to that surface, and the latter only, represented by the line Y, will produce an effect, impelling the kite in the direction O A; and the tension of the string at the same time, in the direction P T S, will cause the machine to ascend in the diagonal O B of the parallelogram O A B T. The ascent of the paper-kite not only depends, as may be thus perceived, on the same principles as those which govern the movement of bodies on inclined planes; but it may be also be fairly affirmed that the path of the kite in rising is an actual inclined plane, up which it is drawn, by the tension and weight of the string.

A well-constructed kite may be made to ascend when there is little or no wind stirring; for, by running with it held by the string and inclined obliquely, the air on its inferior surface will be compressed, just as it would be by running with an expanded umbrella against the wind, and by letting out the string at the same time the kite is drawn up an inclined plane. formed by the compression of the air immediately below it.

ACOUSTICS.

CLXXVII. Acoustics is the science which treats of the nature, phenomena, and laws of sound. It includes the theory of musical concord and harmony, and is, there fore, a valuable and interesting science.

CLXXVIII. Sound is the vibrating or tremulous motions of a sonorous body, communicated through the air to the drum of the ear, and thence to the brain.

Corollary. Hence every body while sounding must be in a state of vibration, which vibration is communicated to the air and propagated by it.

Observation 1. If, when a piece of artillery is fired at a distance, some dust floating in the air, or a cobweb be closely inspected, it will be seen to be agitated at the instant when the report is heard. This proves that the vibrations of the air travel with the same velocity that sound does, and that it is by means of these vibrations striking on the ear-drum that sounds are conveyed.

On what principle is the ascent of the kite explained? CLXXVII. What is Acoustics? What is sound? What is the corollary? What is the first observation?

2. Each vibration of the sounding body is in turn propagated to the particles of air nearest to it, and thence to the more distant until it reaches those particles in contact with the drum or tympanum of the ear, a fine membrane stretched across the ear, and these particles in performing their vibrations strike the tympanum, and this agitates the air in the cavity behind it, which communicates the movement to a chain of four small bones, and these again communicate it to the auditory or hearing nerve, by which it is conveyed to the brain, and there excites in us the idea of sound.

CLXXIX. The principal causes of the variety of sounds, are :—

First, the greater or less frequency of the vibration.

Secondly, The quantity or force of the vibrating materials. And,

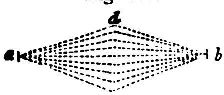
Thirdly, The greater or less simplicity, of the sounds.

Hence arise the height, the strength, and the modification of sounds.

Observation. When sounds are equally acute, they are said to have the same pitch; but when they differ in acuteness, that sound which is shriller is said to be acute, or have a higher pitch; and that which is less shrill, is said to be graver, or to have a lower pitch, or a deeper tone. A difference in pitch, forms the chief character by which musical sounds are distinguished from each other, and is the foundation of their use in music.

CLXXX. The vibrations of a sounding body continue for a longer or shorter time, according as the body is more or less elastic, or as it is thicker or thinner.

Fig. 110.



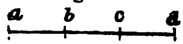
Example. When a string of uniform shape and quality, is stretched between two steady pins, and fixed to them, as *a b*, fig. 110, if it be drawn out of its natural or quiescent position *a b*, into the station *a c b*, and then be let go, it will in consequence of its elasticity, not only come back to its position *a b*, but it will go beyond it to the situation of *a d b*, or nearly as far from *a b*, as *a c b*, was on the other side. All the motion one way, is called one vibration; after this, the string will go again nearly as far as *c*, making a second vibration; then nearly as far as *d*, making a third vibration, and so on; diminishing the extent of its vibrations gradually, until it settles again in its original position *a b*.

Observation 1. During the whole of these vibrations, the string will forcibly act on the air, and produce corresponding vibrations in it, which, reaching and entering the ear, produce on the nerves therein, the sense of sound.

2. The following experiment indicates a curious accordance of vibration, and proves that the air reacts in the exact law of the original vibration :—

What the second observation? CLXXIX. What causes the variety of sounds? CLXXX. On what does the continuance of the vibrations depend, for a longer or shorter time? How may this be illustrated?

Fig. 111.



Experiment. Divide a string as *a d*, fig. 111, into three equal parts, *a b*, *b c*, *c d*, by placing dots at *c* and *b*; place a bridge like a violin bridge, at *b*, also place light bodies, such as small bits of paper, at *c*, and other places of the part *b d*. Then draw a violin bow over the part *a b*; we shall find that all the bits of paper will be thrown off from the part *b d*, excepting the one at *c*; showing that the point *c* remains at rest, whilst the remainder of the string is vibrating, just as though *c* also had a stop, as at *b*.

CLXXXI. Sounds in general are conveyed to the ear by means of the air; but water is also a good conductor of sound; as are timber and flannel.

Experiment 1. A bell rung under water, returns a tone as distinct as if rung in air.

2. If we stop one ear with a finger, and the other by pressing it close to a long stick or piece of deal board, and a watch be held at the other end of the wood, the ticking will be heard, be the stick or board ever so long.

3. If we tie a poker or any piece of metal to the middle of a strip of flannel, about two or three feet long, and then press with the thumbs or fingers the ends of the flannel in the ears, while we swing the poker against an iron or steel fender, we shall hear a sound like that of a very heavy church bell.

4. If two persons stop their ears, they may converse with each other, by holding the two ends of a stick between their teeth, or, only resting the ends of the stick against their teeth. The same may be done by a series of sticks, with the ends touching each other. The same effect is also produced if the end of the stick rest on the throat, or breast, or if one end of it touch a vessel into which the other speaks. In the last instance the sound is most distinct if the vessel is capable of a tremulous motion, as one of glass, bell-metal, or copper.

Sound may also be conveyed from one person to another by a string stretched between their teeth.

CLXXXII. Sound moves at the rate of 1142 feet in a second, or about thirteen miles in a minute.* This is the case with all kinds of sounds, when conveyed by means of air: the softest whisper flies as fast as the loudest thunder.

* The velocity of sound, as here stated, is in accordance with the determination given by Dr. Derham, who is considered as having made the greatest number of accurate and diversified experiments. There is considerable difference observable in the results obtained by different philosophers. Cassini and the other French Academicians, estimated the velocity of sound at 1107 feet per second; the members of the Florentine Academy, at 1148; those of the Royal Academy of Sciences, 1172 Parisian feet; Gassendus computed it at 1473; Mersenne, at 1474; Duhamel, at 1338; Newton, at 968; according to some very accurate experiments, 1130; and Derham, at 1142, which corresponds with Flamstead and Dr. Halley's determination. The Board of Longitude renewed the experiments in the month of June, a year or two since with all possible precision, when it was found that the velocity of sound in the air, at the temperature of 56° Fahr. differs very little from 1044 feet per second.

CLXXXI. What other substances, besides air, convey the vibratory motion of sonorous bodies? What illustrations are given of the power of liquids and solids to conduct sounds? CLXXXII. What is the estimated velocity of sounds through the air?

Observation. The velocity of sound has been applied to the measurement of distances.

1. A ship at sea in distress fires a gun, the light of which is seen on shore 20 seconds before the report is heard, therefore it is known to be at the distance of 20 timee 1142 feet, or little more than 4¼ miles.

2. I see a vivid flash of lightning, and if in three seconds I hear a tremendous clap of thunder, I instantly know that the thunder-cloud is only two thirds of a mile distant, I should therefore retire instantly from any exposed situation.

3. The pulse of a healthy person beats about seventy-six times in a minute; if, therefore, between the flash of lightning and the thunder, I can feel 1 2 3 4, &c. beats of my pulse, I know the cloud is 900, 1800, 2700, 3600, feet from me. A still better method is by a watch having a second hand.

CLXXXIII. Sounds are capable of being reflected by hard bodies, or plane surfaces; and this reflection produces what is called an *Echo;* sound, like light, after it has been reflected from several places may be collected into one point as a focus, where it will be more audible than in any other part; and on this principle whispering galleries are constructed.

Observation. In the reflection of sound, as well as of light, the angle of reflection is equal to the angle of incidence. By the same law, therefore, sound may be collected into a focus.

Experiment 1. If the pulses of air conveying sound be suffered to impinge on a concave surface, the reflected vibrations are converged into a focus.

2. The same effect is produced whenever a number of plane surfaces are so situated that the reflected sounds meet, and cross each other at a certain point. If the ear be placed at this point, the sound will be audible in proportion to the number of surfaces so placed. The famous whispering gallery at St. Paul's, London, is constructed on this principle.

CLXXXIV. Speaking-trumpets, and those which are made to assist the faculty of hearing in deaf persons, depend on the reflection of sound from the sides of the trumpet, and also by its being confined and prevented from spreading in every direction.

Observation 1. A speaking trumpet, to have its full effect, must be directed in a line towards the hearer; the report of a gun or cannon is much louder when fired towards a person, then one placed in a contrary direction.

2. The human voice is produced by the expulsion of air from the lungs, and by the vibration excited in the air, by a very small membrane called the *glottis*, in its passage through the trachea or windpipe; and by the subtile modification of the mouth, tongue, and lips.

To what practical purposes can we apply the uniform velocity of sound? CLXXXIII. What is said concerning the reflection of sound? How is the sound of an *Echo* produced? On what principle are *Whispering Galleries* constructed? What is observed of plane and concave surfaces in converging sound into a focus? CLXXXIV. On what principle are *Speaking-Trumpets* constructed? How is the human voice produced?

3. Singing is performed by a very delicate enlargement or contraction of the glottis, aided likewise by the mouth and tongue for articulation.

4. In stringed instruments the air is struck by the string, and the vibrations of the air produce corresponding sounds in the ear; but in pipes, the air is forced against the sides by the breath, and its vibrations or tones produced by the reaction of the sides.

CLXXXV. An echo is the reflection of sound striking against a surface fitted for the purpose, as the side of a house, a brick-wall, hill, &c., and returning to the ear at distinct intervals of time.

Observation 1. If a person stand about 65 or 70 feet from such a surface, and perpendicular to it, and speak, the sound will strike against the wall and be reflected, so that he will hear it as it goes to the wall, and again on its return.

2. If a bell, situated in the same way be struck, and an observer stand between the bell and the reflecting surface, he will hear the sound going to the wall, and again on its return.

3. If the sound strike the wall obliquely, it will go off obliquely, so that a person who stands in a direct line between the bell and the wall, will not hear the echo.

CLXXXVI. Concord is a succession of sounds that excite in the ear certain agreeable sensations. Sound is therefore the subject matter of musical science. *Harmony* is the coincidence of two or more sounds, which by their union afford to the mind pleasure and delight.

Observation 1. Concord arises from the agreement of the vibrations of two sonorous bodies; so that some of the vibrations of each strike upon the ear at the same instant.

Thus if the vibrations of two strings are performed in equal times, the same tone is produced by both, and they are said to be in *Unison*. If the vibrations strike the ear at different times there is no unison.

2. Concord is not confined to unison. In this case no variety of tones would be produced. It is the effect of agreement between vibrations.

Illustration. If the vibrations of one string are double those of another in the same time, the second vibration of the one, will strike upon the ear at the same instant with the first vibration of the other; this makes the concord of an *octave*.

CLXXXVII. Two strings of equal length, tension, and thickness, by performing their vibrations together, will sound the same note, or be in unison. Two pipes of the

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What parts are concerned in the modulation of the voice in singing? How does the production of sound by pipes differ from that by strings? CLXXXV. What is an *Echo*? How is an echo accounted for? What is observed concerning the reflection of sound and light following the same laws? CXLXXVI. What is *Concord*? From what does concord arise? How are harsh jarring sounds or *Discords* produced?

same length and diameter, will agree in the same manner. Large instruments and long-strings produce grave or deep tones; small instruments and short strings produce acute and high tones.

Observation 1. In the case of the strings, the air is struck by the body, and the sound is excited by the vibrations; in that of the pipes the body is struck by the air, but as action and reaction are equal, the effect is the same.

2. Let a musical string of any length be divided into two equal parts by a bridge in the middle; and the sound of each half is eight notes, or an octive, higher than the tone of the whole string.

Organ-pipes produce grave or acute tones in proportion to their length and size. It is the shortest string of a harpsichord or piano-forte which yields the highest notes.

CLXXXVIII. Sounds may be conveyed to a much greater distance through a continuous tube, than through the open air.

Illustration. Pipes are used in hotels and in the parlours of our private dwellings, running from one room to another to convey orders to the servants.

Dr. Herschel employed a similar tube attached to his forty feet telescope for communicating his observations to an assistant who sat in a small house near the instrument; and thus under cover noted them down, and the particular time at which they were made.

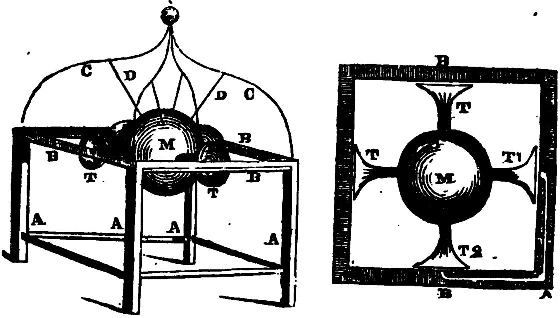
Observation 1. The tubes used to convey sounds are called *Acoustic* tubes.

2. One of the most ingenious deceptions of this kind was an exhibition which took place at Paris several years since and afterward in London, appropriately styled the Invisible Lady, since the apparatus was so contrived that the voice of a female at a distance was heard as if it originated from a hollow globe not more than a foot in diameter, suspended freely from wooden framework, by slender ribands.

A perspective view of the machinery, and a plan of the globe and adjoining parts as constructed by the inventor, M. Charles, are given on page 109. It consists of a wooden frame, much resembling a tent bedstead, formed by four pillars A A A A, connected by upper cross-rails, B B, and similar rails below, while it terminated above in four bent wires, C C, proceeding from the angles of the frame, and meeting in a central point. The hollow copper ball, M, with four trumpets, T T, issuing from it at right angles, hung in the centre of the frame, being connected with the wires alone by four narrow ribands, D D. Any question or observation uttered in a low voice close to the open mouth of one of the trumpets elicited a reply which might be heard from all of them, the sound being perfectly distinct, but weak, as if it was emitted by a very diminutive being.

CLXXXVII. Under what circumstances will two strings or two pipes be in *Unison*? How is an *Octave* concord produced? CLXXXVIII. In what manner may sounds be conveyed to a greater distance than through the open air? What is remarked concerning Dr. Herschel's method of communicating his observations to an assistant? Describe the Invisible Lady.

Fig. 112



3. The real speaker was a female concealed in an adjoining apartment, and the means by which her voice was made to issue from the globe in the manner stated, were at once very simple and ingenious. Two of the trumpet mouths, T^1, T^2, as represented in the plain, were exactly opposite apertures leading to tubes in two of the cross-rails, which meeting at the angle A, opened into another tube descending through the pillar, and which was continued under the floor into an adjoining apartment, where a person sitting might hear what was whispered into either of the trumpets, and return an appropriate answer by the same channel. This machinery differs from the common speaking-tubes, previously noticed, merely in the addition of the hollow ball and trumpets, by means of which the voice is reflected from the cavity of the globe through the trumpets T^1, T^2, into the tube of communication; and thus the effect produced is rendered abundantly mysterious to those unacquainted with the principles of Acoustics.

OPTICS.

CLXXXIX. This science treats of the laws of light, and of vision.

Observation. The term optics is derived from a Greek word signifying to see, and is often divided into three departments: *Catoptrics*, or reflected light; *Dioptrics*, or refracted light, and *Chromatics*, or the phenomena of colours.

CXC. Light is that principle which through the organs of sight, produces in us the sensation of vision, or in other words, renders objects visible.

CLXXXIX. Define optics and the division of the subject. CXC. Define light, and the theories of it.

CXCI. Two theories have been given to explain the phenomena of light. According to one, light consists of a great number of particles of matter, emanating from luminous bodies in all directions, and that these particles are exceedingly small. According to the other, all space is filled with a fluid incomparably more rare than the air or any other fluid, and which is denominated a *luminous ether*, and that the undulating motion in this fluid produces in us the sensation of vision, as sound is transmitted through air, or waves over the surface of water.

Observation. Both of these theories have had powerful advocates. Newton and philosophers generally during his day, and until about the middle of the last century, advocated the theory of emanation; since which time, the theory of undulation has been gradually gaining ground. M. Arrago, Sir John Herschel, and Sir David Brewster who are at the head of this department of philosophy, are advocates of the undulatory theory. Still, most of the facts may be explained by either; some more rationally by the first, and others, by the second.

We shall not advocate either theory in these pages, because either of them will account for all the phenomena of light.

CXCII. A *Ray, or Pencil of Light*, is any exceedingly small portion of light which comes from a luminous body. A *Beam* of light, is a body of parallel rays; a *Pencil* of rays, is a body of diverging or converging rays.

CXCIII. Any body which is transparent, or which affords a ready passage for light, is called a transparent *medium*, as air, glass, water, &c. Bodies which do not allow the passage of light through them, are called *opaque*, as stone, wood, &c. *Translucent*, is where light is transmitted, but where objects cannot be distinctly seen, thus a thin sheet of writing paper is translucent, but not transparent.

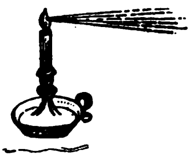
CXCIV. Rays of light which, coming from a point, continually separating as they proceed, are called *Diverging Rays*. Rays which tend to a common point are called *Converging Rays*. When the lines in which they move are parallel, they are called *Parallel Rays*.

What observations on these theories? CXCII. Describe a pencil of light, beam of light, and pencil of rays. CXCIII. What is a medium, an opaque body? CXCIV Define diverging, converging, and parallel rays.

CXCV. The point from which diverging rays proceed, is called the *radiant point;* that to which converging rays are directed, is called the *focus.* A ray of light, bent from a straight course in the same medium, is said to be *inflected;* when turned back on the surface of a body, it is said to be *reflected;* and, when turned out of its course as in passing out of one medium into another, it is said to be *refracted.*

CXCVI. Light moves in straight lines, in every direction, from a luminous body, the rays or lines diverging in their passage, and forming what is called a pencil of light, as seen in the wood cut.

Fig. 113.



That light moves in straight lines, may be shown by the following experiments:—

Experiment 1. Let a portion of a beam of light be intercepted by any body; the shadow of that body will be bounded by straight lines passing from the luminous body, and meeting the lines which terminate the opaque body.

2. A ray of light, passing through a small orifice into a dark room, proceeds in a straight line.

3. Rays will not pass through a bended tube.

CXCVII. A similar effect may be produced by admitting into a darkened room, through a minute aperture in a window-shutter, the light of the sun which would be perceived proceeding in a diverging bundle or pencil of rays; and on presenting to it a flat board, a luminous image would be formed, increasing in diameter with the increase of distance from the aperture at which the plane was held, and which, by variously inclining the plane, might be made to assume elliptical or other curved figures.

CXCV. Define the radiant point, the focus, the reflected, inflected, and refracted ray. CXCVI. How does light move—and what experiments to prove the position? CXCVII. What experiment may be produced in a darkened room?

CXCVIII. Images of variously shaped bodies seen by light thus admitted through a small opening are always in a reversed position, in consequence of the obliquity or divergence of the rays of light.

Fig. 114.

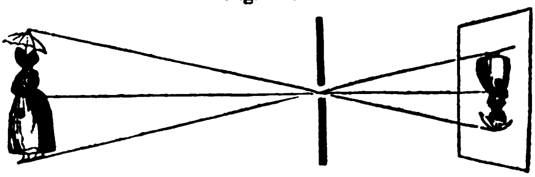


Illustration. That this effect must take place will be readily perceived from the preceding figure, which shows that the rays in passing through the opening must cross each other, and thus rays coming from the superior parts of objects, impinge on the relatively inferior portion of the plane, and those from the higher parts strike on that portion of the plane, below the other rays; the spectra or images produced must consequently be inverted.

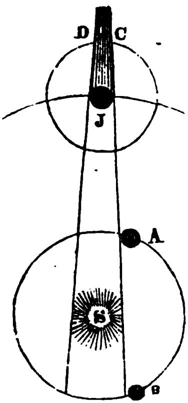
CXCIX. The rays or vibrations of light are progressive, and move with a velocity much greater than that of sound; for the flash of a gun, fired at a considerable distance, is seen some time before the report is heard. The clap of thunder is not heard till some time after the lightning has been seen.

Observation 1. If the transmission of light were instantaneous, it must be obvious that the reflected light of the sun would take up no more time in passing from any one of the planetary bodies to the earth, when they are farthest from us, than it does when they are nearest; and as the situation of the earth with respect to the other planets is different in different parts of her orbit, the satellites of Jupiter, on emerging from the shadow of that planet, would be seen as quickly when the earth was in one part of her orbit as in another. But this is by no means the case; and the effect of the transmission of light is such, that when the earth is between Jupiter and the sun, the satellites, after being eclipsed, are perceived rather more than eight minutes sooner than they ought to appear according to the time as calculated by the most accurate tables; and when the earth is in the opposite part of her orbit, so that the sun is between this planet and Jupiter, the satellites emerge about eight minutes later than the calculated or mean time.

In the annexed diagram, let S represent the sun, A and B the earth in different parts of her orbit, J, Jupiter, D, his nearest satellite entering the shadow of that planet, and C, the same satellite, emerging from the shadow.

CXCVIII. What is said of the reversed position of images? CXCIX. How is it proved that the motion of light is progressive, and not instantaneous?

Fig. 115.



Now the time of the commencement or termination of an eclipse of the satellite, as stated from calculation in tables, is the instant at which the satellite would appear to enter or emerge from the shadow, if it could be seen by an observer from the sun: and it is found from repeated observation, that the eclipse takes place about 8 minutes earlier than the calculated period, when the earth is in the nearest part of her orbit, as at A, and 8 minutes later when she is in the opposite part of her orbit, as at B. Hence it will be apparent that light takes up 8 minutes in passing through a space equal to half the diameter of the earth's orbit, or the distance between the earth and the sun, which is nine-five millions of miles; so that it moves at the rate of $95,000,000 \div 8 \times 60 =$ 197,916 nearly 200,000 miles in one second.

2. On account of the progressive motion of light, it is evident that if a luminous body were suddenly placed in the heavens, at the same distance, for instance, that the Sun is from us, we could not possibly see it before the lapse of about 8¼ minutes; and if the Sun were suddenly annihilated, we should not discover the phenomenon, until about 8¼ minutes had elapsed. Also, if any of the fixed stars were suddenly destroyed, their appearance to us would be the same for about three years.

Again, when we perceive a celestial object, we do not see it exactly in the place where it actually is; but we see it in the place which corresponds to the change of place by the Earth, during the progress of light from the body to the Earth.

CC. The particles of light must be exceedingly small, if they are particles; or the force of the vibrations must be very delicate; otherwise their velocity would render their momentum too great to be endured by the eye without pain.

CCI. The quantities of light, received from a luminous body upon a given surface, are inversely as the squares of the distances of the surface from the luminous body.

Illustration 1. Thus, suppose a candle to be placed at the distance of one yard from the face of a dial or time-piece, the light thrown on it may be represented by the number 1; if then it be removed back to two yards, the light will be but ¼ as much as before; at 3 yards 1-9, at 4 yards 1-16, at 5 yards 1-25, at 25 yards 1-625.

2. This reduction of light, in proportion to the distance of the luminous body, is the necessary effect of the divergence and consequent dispersion of the radiant pencil; and hence it may readily be conceived, than an incon-

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What remark on Jupiter's satellites? What on the sun and fixed stars, and what on the real and apparent place of heavenly bodies? CCI. What is the quantity of light received on a luminous body? Give illustrations 1 and 2.

siderable light can only be visible at a comparatively trifling distance, and that its influence in rendering non-luminous objects visible, must be limited to a much shorter distance than the extreme point at which its light will be perceptible.

CCII. If rays proceed from a radiant point at an infinite distance, their divergency is so trifling, that they may be considered as parallel.

Observation. Hence all the rays which could come from the centre, or any other given point, of the sun's surface, are considered as parallel at the immense distance of the earth.

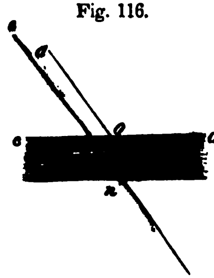
DIOPTRICS.

CCIII. When rays of light pass *obliquely* out of one transparent medium into another, which is either more dense, or more rare, they are bent out of their former course, and they are then said to be REFRACTED.

CCIV. Rays of light are always refracted *towards* a perpendicular to the surface in entering a *denser* medium; and this refraction is, more or less, in proportion as the rays fall more or less obliquely on the refracting surface.

Illustration 1. Let *c d*, fig. 116, represent a thick plate of glass, or a vessel of water, and *a o*, a ray of light refracted at *o*, and entering the denser medium so that instead of continuing in the direct line, it moves in the direction *o n*; but when it passes out of this medium into air at *n*, it is again bent away from the perpendicular to the medium and moves in a direction parallel to *a o*.

Fig. 116.

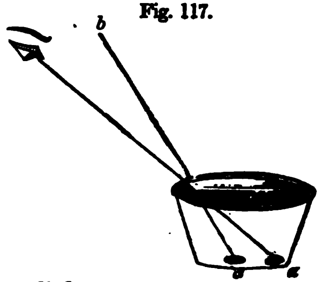


2. Refraction of water may be shown in another way: Prepare a black-

CCII. What is said of rays from an infinite distance? CCIII. What are refracted rays? CCIV. What are the laws? Illustrate refraction by fig. 116?

ened vessel and place it in such a position that the spectator in a given place cannot see the bottom, now pour in a few globules of quicksilver or place a bright silver coin on the bottom, this will not be seen by the spectator but by filling the vessel with water, the metal on the bottom will be distinctly seen from the refracting power of the water. The truth of the remarks above, will be verified by inspecting fig. 117, where the eye could not see the metal *c*, while the vessel was empty except by raising it to the position *b*, but on filling the vessel with water, the object by refraction, is raised to *a*, where the rays proceeding from it reach the eye of the observer. Objects seen obliquely in water appear elevated.

Fig. 117.



CCV. When light passes out of a denser into a *rarer* medium, it moves in a direction *farther from* the perpendicular.

Illustration 1. It will be perceived by tracing the line indicating the ray of light proceeding from the shilling in fig. 117, that when it passes from the water into the atmosphere, that it bends away from a line perpendicular to the surface of the water.

2. Take a glass goblet half filled with water, and put a half dollar into it, and invert over it a small plate or saucer. The bystander will suppose that he sees two pieces, the one a half dollar, and the other a dollar—the first is seen by the rays refracted from the surface of the water, and the second from refraction through the side and through the rounded side of the goblet.

3. Another example of refraction may be seen by putting a staff obliquely in the water and observing that it will always appear as if bent at the surface of the liquid. In like manner, by observing the sandy bottoms of rivers, objects on the bottom appear more elevated than they really are, from the refraction of the rays of light.

4. Rays which pass perpendicularly from one medium to another, suffer no refraction.

CCVI. The *Angle of Incidence*, is that which is contained between the line described by the incident ray, and a line perpendicular to the surface on which the ray strikes,

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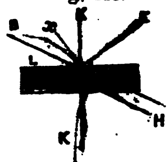
Illustrate it by the piece of money, fig. 117. CCV. Describe the laws of refraction. Give illustrations 1 and 2. Describe refraction by the staff in water. Give the fourth illustration. CCVI. Describe the angle of incidence.

raised from the point of incidence. Thus in fig. 118, the angle B C K is the angle of incidence.

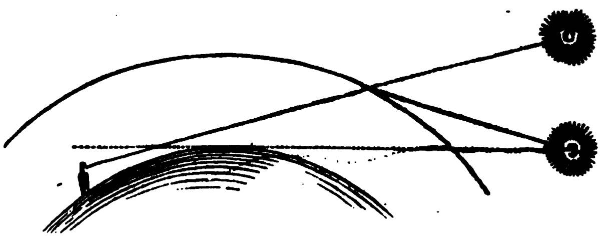
CCVII. The *Angle of Reflection*, is that which is contained between the line described by the reflected ray and a line drawn perpendicular to the reflecting surface at the point in which the ray passes through that surface. Thus, in fig. 118, E C K is the angle of reflection.

Fig. 118.



CCVIII. As the effect of any transparent medium, in the refraction of light, generally increases with increase of density, so air and vapours when dense display greater power of refraction than when comparatively rare; and hence some curious and important phenomena depend on atmospheric refraction.

Fig. 119.



CCIX. Light, on entering the atmosphere of the earth, encounters a medium less rare than the more ethereal space beyond it, and as the lower portion of the atmosphere is relatively the densest, rays passing through the air from objects far above us must be considerably re-

CCVII. Describe the angle of reflection. CCVIII. What effect on refracting power has the increase of density? CCIX. What atmospheric phenomena depend on this refractive influence? Explain by diagram the effect of refraction on the apparent place of the heavenly bodies.

fracted. From this cause the sun and other celestial bodies are never seen in their true situations, unless they happen to be vertical; and the nearer they are to the horizon, the greater will be the influence of refraction in altering the apparent place of any of those luminaries.

Illustration. Thus the spectator, in fig. 119, will see the sun at C, when it is in reality at S, from the refraction of the atmosphere.

CCX. Availing themselves of the principle of *refraction*, philosophers have so contrived surfaces, that the perpendiculars to them constantly vary, and produce new and important effects. This they have done by means of convex and concave glass *lenses*, so as to collect or disperse the rays of light which pass through them.*

Observation. Lenses are of various kinds, named according to their forms.

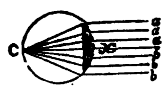
Fig. 120.

A *Plano-convex lens* has one side flat, and the other convex, as A, fig. 120.
A *Plano-concave* is flat on one side, and concave on the other, as B, fig. 120.
A *Double-convex* is convex on both sides, as C, fig. 120.
A *Double-concave* is concave on both sides, as D, fig. 120.
A *Meniscus* is convex on one side, and concave on the other, as E, fig. 120.
The *Axis* of a lens, is a line passing through the centre; thus, F G is the axis to all the five lenses.

CCXI. If parallel rays fall upon a plano-convex lens, they will be so refracted as to unite in a point behind, called the *principal focus*, or *focus of parallel rays*.

Example. Thus the parallel rays *a b*, fig. 121, falling upon the *lens* are refracted towards the perpendicular C *x*, and unite in a focus at C.

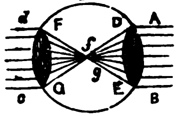
Fig. 121.



* A *Lens* is a round piece of polished glass, which has both its sides spherical, or one spherical and the other plane.

CCX. What is a *Lens*? What are the various kinds of lenses; and how are they designated? What is the *Axis* of a lens? CCXI. If parallel rays fall upon a *plano-convex* lens, what is the effect of their refraction?

Fig. 122.



CCXII. The distance from the middle of the glass to the focus, is called the *Focal Distance;* which focal distance, in a plano-convex lens, is equal to the diameter of the sphere of which the lens is a portion, fig. 121, and the focal distance of a double-convex lens is equal to the radius or half the diameter of a sphere of which the lens is a portion, fig. 122. All the parallel rays of the sun which pass through a convex glass as DE, are collected in its focus *f*, and the force of the heat at the focus is to the common heat of the sun, as the area of the glass is to the area of the focus.

Illustration. If a lens four inches in diameter collect the sun's rays into a focus at the distance of twelve inches, the image will not be more than one-tenth of an inch in diameter; the surface of this little circle is 1600 times less than the surface of the lens, and consequently the heat will be 1600 times greater at the focus than at the lens.

Corollary 1. Hence the construction of common burning-glasses, which are all double-convex lenses.

2. Hence the reason that furniture has been set on fire by leaving a globular decanter of water incautiously exposed to the rays of the Sun, which acts as a double-convex lens.

Observation. The burning-glass made by Parker for Dr. Priestly, was a double-convex lens of flint glass, *three* feet in diameter, three inches thick in the middle, and weighing 212 pounds. Its focal distance was *six* feet *eight* inches, and it produced a heat that melted fragments of iron in a moment. It melted 20 grains of gold in *four* seconds—20 grains of silver in *three* seconds—10 grains of platina in three seconds, and as much flint in thirty seconds.

CCXIII. If another double-convex F G, fig. 122, be placed in the rays at the same distance from the focus, it will so refract the rays back again, that they *will* go out of it parallel to each other.

Illustration. It is evident that all the rays, except the middle one, cross each other in the focus *f*, of course the ray D A, which is uppermost in going in, is the lowest in going out, as G *c*.

Experiment 1. If a candle be placed at *f*, the diverging rays between F G, will, upon going out of the lens, become parallel at *d c*.

2. If a candle be placed nearer the glass than the focus, the rays will *diverge*, after going through the lens.

CCXII. What is meant by *Focal Distance?* What is the rule for determining the focal distance of a plano-convex lens? How is the focal distance of a *double-convex* lens ascertained? What is the proportion between the degree of heat in the focus of a burning-glass, and the common heat of the Sun? What kind of lens is a common burning-glass? How may some accidents by fire be accounted for? What is said of the burning-glass made by Parker? CCXIII. What effect will another double convex lens have, when placed in the refracted rays at the same distance from the focus of the given lens? Illustrate proposition 213, and explain the experiments.

3. If the candle be placed farther from the glass than the focus, the rays will *converge*, after passing through the glass, and meet in a point which will be more or less distant from the glass, as the candle is nearer to, or farther from, its focus.

4. When the rays meet, they will form an inverted image of the flame of the candle. Suppose B, a candle, fig. 123, and C a convex lens, then on a dark screen, D, the image A of the candle will be produced, and will be reversed, because the rays cross each other in passing through the lens.

Fig. 123.

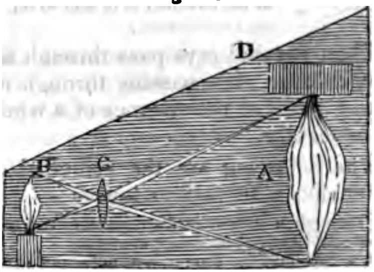
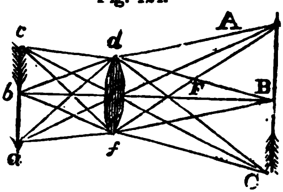


Fig. 124.



5. If an object A B C, fig. 124 be placed beyond the focus F of the glass *d e f*, some of the rays which flow from every point of the object on the side next the glass, will fall upon it, and after passing through it they will be converged into as many points on the opposite side of the glass, where the image of the whole will be formed, which will be inverted. Thus the rays flowing from A, as A *d*, A *e*, A *f*, will converge in the space *d e f*, and by meeting in *a* will there form the image of the point A; and so of those rays flowing from B and C, and of course of all the intermediate parts.

6. If the object A B C, be brought nearer to the glass, the picture *a b c* will be removed to a greater distance from it.

7. The picture will be as much larger or less than the object, as its distance from the glass is greater or less than the distance of the object.

CCXIV. When parallel rays pass through a double concave lens, they will diverge after passing through the

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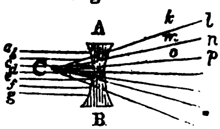
CCXIV. When parallel rays pass through a double-concave lens, what is their direction?

glass, as if they had come from a point in the centre of the concavity of the glass.

Fig. 125.



Example. If the rays *a b c*, &c., fig. 125, pass through A B, and C be the centre of concavity, then the ray *a* after passing the glass, will go on in the direction *k l*, as if it had come from *c* and no glass in the way; the ray *b* will go on in the direction *m n*, and so on.

CCXV. When parallel rays pass through a plano-concave lens, they diverge after passing through it, as if they had come from a point at the distance of a whole diameter of the glassy concavity.

CCXVI. The following are the principal phenomena of rays in connexion with various lenses :—

Observation 1. Through a *convex surface*, passing out of a rarer into a denser medium, *parallel rays* will become converging.

Diverging rays, will be made to diverge less, to become parallel, or to converge, according to the degree of divergency before refraction, or of the convexity of the surface.

Converging rays, towards the centre of convexity, will suffer no refraction, because they will be perpendicular to the refracting surface.

Converging rays, tending to a point beyond the centre of convexity, will be made more converging.

Converging rays, towards a point nearer the surface than the centre of convexity, will be made less converging by refraction.

But when the rays proceed out of a denser into a rarer medium, the reverse occurs in each case.

2. When rays proceed out of a rarer into a denser medium, through a CONCAVE SURFACE, if *parallel* before refraction, they are made to diverge.

If they are *divergent*, they are made to diverge more, to suffer no refraction, or to diverge less, according as they proceed from some point beyond the centre, from the centre, or from some point between the centre and the surface.

If they are *convergent*, they are either made less converging, parallel, or diverging, according to their degree of convergency before refraction :—

And the *reverse*, in passing out of a denser into a rarer medium.

Experiment. Most of the preceding propositions may be confirmed, in a room from which all external light is excluded, by placing a convex or concave lens, fixed in a frame which moves perpendicularly upon an oblong bar of wood, or table, at different distances from a lighted candle placed perpendicularly on the same bar of wood, and receiving the images upon white paper. Upon this bar of wood, on one side of a line over which the convex lens is placed, let a line, perpendicular to the last mentioned line, be divided into parts, 1, 2, 3, 4, &c., each equal to the distance of the focus of parallel

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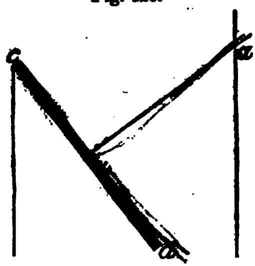
CCXV. What is stated concerning parallel rays passing through a plano-concave lens? CCXVI. What are the principal phenomena of rays in connexion with various kinds of lenses? What experiment is explanatory of these phenomena?

rays; and on the other side of the lens, let a line be divided in the same manner, and let the first division, which is farther from the lens than the focus, be subdivided into parts respectively, equal to $\frac{1}{2}$, $\frac{1}{3}$, &c., of the distance of the focus of parallel rays; if a candle be placed over the division 2, it will form a distinct image on a paper held over the division $\frac{1}{2}$; if a candle be over 3, the image will be at $\frac{1}{3}$, &c., whence it appears, that the distances of the correspondent foci vary reciprocally; or, by holding a large double-convex lens, or burning-glass, in the sun's rays, and receiving the image on white paper, or other substance at different distances.

REFLECTION.

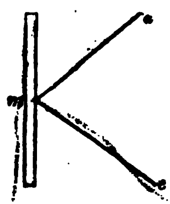
CCXVII. Let a ray of light be admitted through a hole in the shutter *a*, of a dark room, so as to fall perpendicularly upon the inclined mirror, or looking-glass *c d*, it will be reflected back in the same track through which it proceeded.

Fig. 126.



CCXVIII. If the incident ray *a* fall upon the mirror, in an oblique direction, as *a m*, fig. 127, it will be reflected in the oblique direction *m e*; which last is called the reflected ray.

Fig. 127

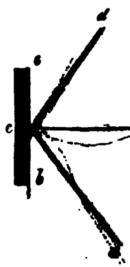


CCXVII. Illustrate reflection. CCXVIII. Illustrate the incident and reflected ray.

CCXIX. The angle of incident is equal to the angle of reflection; or in other words, the angle contained between the incident ray, and a line drawn perpendicular to the mirror is equal to that contained between the reflected ray, and the same perpendicular line.

Illustration. Let *d c*, fig. 128, be the incident ray, and *a c* the reflected ray; let *f c* be the perpendicular line, *b e* the mirror: there it will be evident from inspection that the angle *d c f*, is equal to the angle *f c a*.

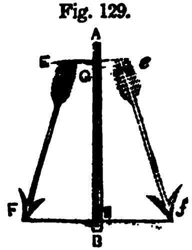
Fig. 128



CCXX. *Mirrors* are of three kinds, namely, *plane*, *convex*, and *concave*. They are made of polished metal, or of glass covered on the back with an amalgam of tin and quicksilver.

CCXXI. The relative position of the image of an object as seen in a reflecting plane will be such that every part of the image will appear as far behind the plane as the object itself is before it.

Fig. 129.

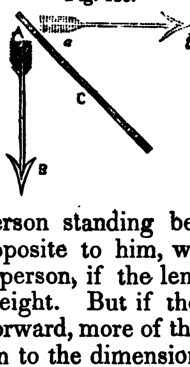


CCXIX. Describe the law on the angles of incidence and of reflection. CCXXI. Explain the relative position of parts of an image formed by a reflecting plate.

Illustration. Let A B represent a plane mirror, and E F any object, as an arrow; then draw from the points E and F, the perpendiculars E G and F H to the surface of the mirror, and produce those lines to e and f, so that E G shall be equal to e G, and F H to f H, and $e f$ will be the position of the image which will be exactly equal to the object as the quadrilateral figure G $e f$ H will be equal to the quadrangle G E F H. From inspection of this figure it will be perceived that the rays of light proceeding from that part of the object nearest to the surface of the mirror will be reflected so as to form the part of the image nearest to the plane of the mirror in the opposite direction. Hence when trees or buildings, or any other objects, are reflected from a horizontal plane, as the surface of a pond, or a smooth stream of water, they will appear inverted; for their lower parts being nearest to the reflecting surface are seen immediately within it, while their tops seem to hang downward or to extend deeper beyond the surface.

CCXXII. When a mirror, C, in the following figure, is inclined forward at an angle of 45 deg. an object A B, if placed in a vertical position, will form a horizontal image a b; and if the position of the object be horizontal, that of the image will be inverted.

Fig. 130.



CCXXIII. A person standing before a plane mirror placed vertically opposite to him, will not perceive the image of his whole person, if the length of the mirror be less than half his height. But if the upper part of the mirror be inclined forward, more of the image will become visible, in proportion to the dimensions of the mirror, than when it is placed vertically; and hence a person may view himself from head to foot in a looking-glass less than half his length.

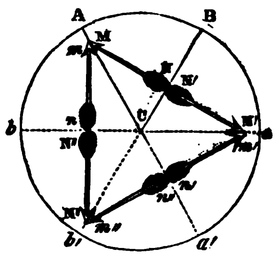
CCXXIV. A number of images may be formed, and

Why do trees, buildings, or other objects seen by reflection from a surface of water, appear inverted? CCXXII. How may a vertical object be made to produce a horizontal image? CCXXIII. How long must a vertical plane mirror be, in order that the whole person may be seen by an eye immediately in front of it? What expedient enables us to see the whole person in a small mirror? CCXXIV. What effects produced by two mirrors?

peculiar effects produced by means of two mirrors, either inclined or parallel, and opposite to each other, for the image of an object which is delineated behind one mirror may thus serve as an object to be reflected from the surface of another mirror.

Illustration. If any object as M N be placed between two plane mirrors inclined towards each other at an angle A C B several images will be perceived, all situated in the circumference of the circle. This may be demonstrated by drawing the image in its place behind each mirror, and considering each image as forming an object in its turn, the image of which is also to be drawn. Thus it will be perceived that the image of M N in the mirror A C is m n, while its image in B C is M′ N′; and in the same manner the image formed by the reflection of the first image m n in b C will be M′ N′, while the image of M′ N′ in a C will be m' n'. It will further appear that m'' n'' is the image of both M″ N″ in the mirror b' C, and of m' n' in the mirror a' C, one of the images covering the other, if the angle A C B be 60 degrees, or the sixth part of a circle as in the diagram; but if the angle be any greater or less, the image m'' n'' will be twofold: that is the two images will not exactly coincide. On this principle is formed the Kaleidoscope invented by Sir David Brewster, and by means of which the reflected images viewed from a particular point, exhibit symmetrical figures under an infinite variety of arrangements of beautiful forms and colours.

Fig. 131.



CCXXV. If two mirrors be placed opposite and parallel to each other, an indefinite number of images will be perceived, becoming more and more indistinct by repeated reflections, till at last they vanish in obscurity.

Observation. This effect may be advantageously observed in an apartment where two mirrors are fixed in opposite sides of it, with a lustre, or some such object between them. Rooms fitted up in this manner will present to the spectator an interminable vista on every side, apparently filled with a multiplicity of objects.

Give the illustration. What is this instrument denominated? CCXXV. How can an indefinite number of images be produced by means of two mirrors? Where is this advantageously observed?

CCXXVI. Amongst natural phenomena produced by reflection of light, the most important is atmospheric reflection. Some of the less usual phenomena of this class are extremely curious such as the mirage, and a variety of aerial spectra of an analogous kind. The mirage is generally perceived on sandy plains in hot climates, as in Egypt and in South America; and it has been often described by travellers.

Illustration 1. In the middle of the day, when the sun shines on the level surface of the sand, the appearance of a sheet of water is observed at the seeming distance of about a quarter of a mile; the deception being so complete, that any person unacquainted with its cause would inevitably suppose he was approaching a lake or river. Like real water, the spectral lake reflects objects around; so that houses, trees, and animals, are perceived with the utmost distinctness in this singular mirror. As the observer advances, the visionary stream recedes, still keeping at the same apparent distance, but with changes of scene, by the disappearance of images first beheld, and the formation of new ones from other objects, as they successively become liable to reflection.

2. The French philosopher Monge, who witnessed this phenomenon in Egypt, published a satisfactory explanation of it in the first volume of the *Decade Egyptienne;* and about the same time a similar exposition of the cause of it was given by Dr. Wollaston, in the London Philosophical Transactions. The latter also produced an artificial mirage in the heated air over a mass of red-hot iron; and he observed the same appearance in bodies seen across the surfaces of two differently refracting fluids placed one above the other in a transparent vessel.

3. He thus accounts for the phenomenon; in the middle of the day, the sandy soil becoming very hot, the stratum of the air in contact with it acquires a very elevated temperature, and hence, being dilated, its density is found inferior to that of the strata immediately above it, and the luminous rays which fall on this dilated stratum, at an angle comprised within a certain limit of 90 degrees, are reflected at its surface as from a mirror; and they convey to the eye of the observer the reversed image of the lower parts of the sky, which are seen on the prolongation of the rays received, and consequently appear below the real horizon. In this case, if nothing corrects the error, the limits of the horizon will appear lower and nearer than they really are.

4. If any objects, as villages, trees, or the like, render it evident to the observer that the limits of the horizon are more remote, and that the sky is not so low as it seems, the reflected image of the sky will appear to form a reflecting plane of water. The villages and the trees will emit rays which will be reflected just as rays would have been if coming from the part of the sky intercepted by them. These rays will produce a reversed image below the objects seen by the direct rays. The limit at which the luminous rays begin to be reflected being constant, and the rays that form the largest angle

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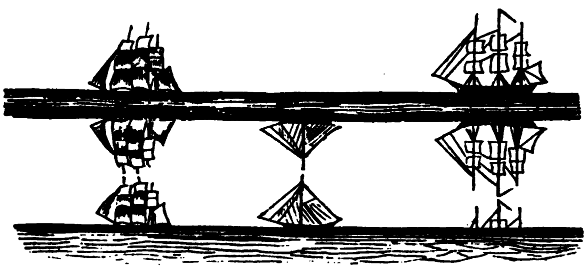
CCXXVI. How is the *mirage* formed? Give some account of that appearance. How may the effect be imitated? What explanation did Wollaston give of that phenomenon? How is the imagination led to the supposition that the reversed image of the lower part of the sky is nearer and lower than the true visible horizon? How does it appear that trees, buildings, &c., ought to appear reversed in the inverted image of the sky?

with the horizon appearing to come from the nearest spot to where the phenomenon commences, this point must be a constant distance from the observer; hence if he advance, the border of the lake will appear to recede which accords with the facts as they are observed.

CCXXVII. Those appearances called *Looming*, or the elevation of objects seen in the distant horizon above their usual level, are explained on the same principle as the mirage. Under this head is included the *Fata Morgana*, observed in the straits of Messina, and the singular apparitions of ships and other objects in the air, sometimes in a direct, and sometimes in an inverted position.

Illustration. The following illustrations are taken from the aerial appearances at the Cliffs of Dover, England, in May, 1835. Where the real ship is visible, a double image may be formed, consisting of an inverted figure immediately over the ship itself, and another figure in an erect position, above the preceding. If there is a single figure only, it will usually be inverted with respect to the real ship below it. Sometimes a double image, or an erect figure with one below it inverted, will appear where the vessel thus reflected is wholly invisible, or perhaps its topmasts be seen, while the remaining parts are hid from the convexity of the earth's surface.

Fig. 132.



CCXXVIII. The manner in which these and similar phenomena may be caused by reflection may be comprehended by reference to the analogous effect of spherical mirrors subsequently noticed. But it is probable, that where double images of objects appear, the effect depends chiefly on the refraction of light, owing to the varying density of the atmosphere; and the circumstances under which such a state of the air may be produced have been

CCXXVII. Explain the phenomenon denominated looming. Give the illustration. How will the appearance of spectre-ships be affected by the nearness or remoteness of the real ships which cause the spectra? CCXXVIII. How is refraction affected by change of density in the air?

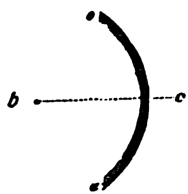
pointed out and illustrated by Dr. Wollaston. The refraction being greatest where the change of density is the most rapid, and less on each side of this point, the whole effect must be similar to that of a convex lens.

CCXXIX. In reference to the Fata Morgana, Dr. T. Young says: "It may frequently happen in a medium gradually varying, that a number of different rays of light may be inflected into angles equal to the angles of incidence, and in this respect the effect resembles reflection rather more than refraction."

CCXXX. A convex mirror consists of any given portion of the exterior surface of a sphere.

Illustration. Thus *a e*, fig. 133, represents a portion of a sphere of which *b* is the centre, and the line *b c*, which is defined as a line passing through the centre, and perpendicular to the surface; all such lines are called radii to the circle, of which the mirror forms a part.

Fig. 133.



CCXXXI. The image formed by a plane mirror, as we have already seen, is of the same size as the object, but the image reflected from the convex mirror is always smaller than the object.

Observation. As objects are always seen in the direction in which the rays approach the eye, the image of objects seen by means of mirrors always appear behind the mirror.

CCXXXII. The effect of light reflected from a convex mirror is to produce a miniature picture of any objects

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CCXXIX. What circumstance of the air may cause varying rays of incident light to be reflected to a focus? CCXXX. What are convex mirrors? Give the illustration. CCXXXI. What is the relative size of images in plain and convex mirrors? CCXXXII. In convex mirrors where is the image?

placed opposite to it; the images thus formed appearing, to the eye of the observer in front, to be situated within, or behind the mirror.

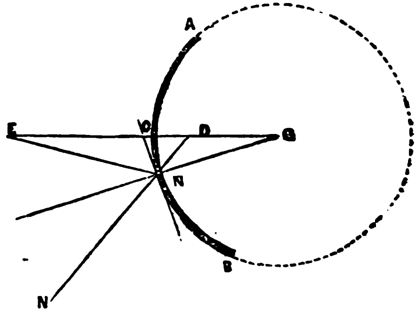
Illustration. Thus the globular bottles filled with coloured liquid, in the window of a drug-store, exhibit all the variety of moving scenery without, such as carriages, carts, and people moving in different directions: the upper half of each bottle exhibiting all the images inverted while the lower half exhibits another set of them in the erect position.

CCXXXIII. The images formed by reflection from a convex mirror, must always be smaller than the objects by which they are produced, because the rays forming them diverge in their passage to the eye of the observer.

Illustration 1. In the annexed figure A B represents a convex mirror which is a portion of a sphere whose centre is S, and the radius (distance from the centre to the circumference) is G C; G is therefore the focus of the mirror.

2. If an object be placed at E at a distance before the mirror. its image will appear behind the mirror at D halfway between G and C, and the image at D will be as much less than the object E as the line D C is less than the line C E, or it will be as much smaller than the object as the line C D is shorter than the line C E.

Fig. 134.



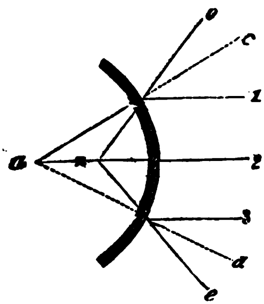
3. If, therefore, the object be brought nearer to the surface of the mirror, the image also will approach to meet it, and become proportionally enlarged; so that if a part of any object be brought into contact with the convex surface of the mirror, the image of that part will appear of precisely the same size as in the object itself; but unless the object be extremely small, or the mirror be a segment of a very large sphere, it must be obvious that only a small portion of an object can be made to touch the mirror, and hence the entire image must ever be to some extent inferior in size to the object by which it is produced.

What illustration is given? CCXXXIII. Why must the image from a convex mirror be smaller than the object? Give the illustrations. Suppose the object be brought near the surface of the mirror, what effect has it on the image?

CCXXXIV. A convex mirror by reflection converts parallel rays into diverging rays, and convergent rays are reflected either parallel or less convergent.

Illustration. First let the parallel rays 1, 2, 3, fig. 135, fall upon the convex mirror, 2 is perpendicular to it, and will be reflected back in the same line, but 1 and 3 striking the reflector obliquely will be reflected in the diverging lines *o* and *e*. Secondly, let *o* and *e* be converging rays, falling upon the mirror, they will be reflected in the parallel lines 1 and 3.

Fig. 135.



CCXXXV. Diverging rays falling on a convex mirror, are rendered more diverging.

CONCAVE MIRRORS.

Observation. The shape of concave mirrors is like that of convex mirrors, with this difference that the former reflect from the inside, and the latter from the outside. The effects of the concave are generally the reverse of those of the convex, the former tends to collect rays to a focus, and the latter to disperse them.

CCXXXVI. The focus of a concave mirror is the point in which the reflected rays meet. The centre of concavity is the centre of the sphere, of which the mirror forms a part. Parallel rays falling on a concave mirror

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CCXXXIV. What effect has a convex mirror on parallel and on converging rays? Give the illustrations. CCXXXV. What effect has the convex mirror on diverging rays? Distinguish between convex and concave mirrors.

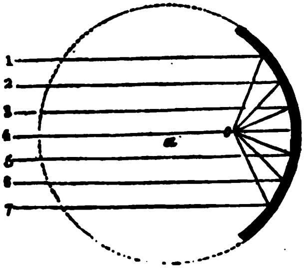
are converged to a focus halfway between the centre of concavity, and the surface of the mirror.

CCXXXVII. The following are the principal phenomena of reflected rays:—

Parallel rays reflected from a CONCAVE surface, are made converging.

Illustration. The parallel rays 1, 2, 3, 4, &c., fig. 136, are converged by reflection from the concave mirror, and meet in the focus *o*, halfway between the centre *a*, and the surface of the mirror.

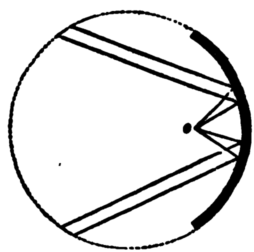
Fig. 136.



CCXXXVIII. Converging rays falling on a concave mirror will after reflection become more converging.

Illustration. Thus in fig. 137, the converging rays after being reflected are rendered more converging, and meet in the point *a*.

Fig. 137.



CCXXXIX. Diverging rays falling upon a concave mirror, if they diverge from the focus of parallel rays, they will become parallel. Thus the rays from *o*, fig. 136,

after falling on the mirror are reflected parallel as seen in 1, 2, 3, &c.

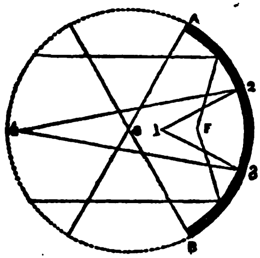
CCXL. If the rays diverge from a point nearer to the mirror than the focus of parallel rays, they will diverge after reflection, but less than before.

Illustration. Thus the rays from *o*, fig. 137, diverge after reflection, but less than before.

CCXLI. If the rays diverge from a point, between the focus of parallel rays, and the centre of the circle of which the mirror forms a part, they will converge after reflection to some point on the opposite side of the centre.

Illustration. In fig. 138, *o* is the centre of the circle; F, the focus of parallel rays. Now the rays 1, 2, and 1, 3, after reflection from the mirror A B, converge to the point 4, beyond *o*, the centre of the circle.

Fig. 138.



CCXLII. If the rays emanate from a point beyond the centre, as from 4, in fig. 138, they will converge to a point on the opposite side of the centre, or between the centre and the surface of the mirror.

Illustration. Thus let 4, 2, and 4, 3, in fig. 138, be the incident rays, they will after reflection converge to a focus at 1.

CCXLIII. If an observer view his own image at a considerable distance beyond the centre of a concave mirror, the image will appear small, faint, and somewhat confused.

Illustration. This is owing to the smallness of the number of rays that

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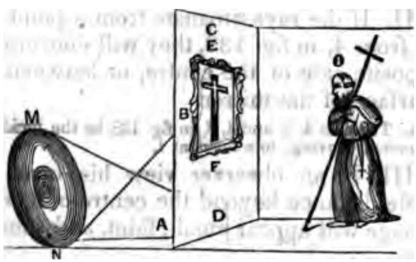
CCXLII. If the rays emanate from a point beyond the centre, where will be the focus? CCXLIII. Why is the image of a distant observer seen indistinctly in a concave mirror?

can enter the eye; hence the apparent distance is augmented or rendered uncertain, so that the image is conceived to be beyond or within the mirror, and this misconception increases the confusion. As the observer advances towards the mirror, his image will gradully appear larger and brighter, and likewise draw nearer to him; but if he do not view it between himself and the mirror, it will continue still indistinct. At length he will arrive at the station whence the image assumes a determinate and correct figure, appearing perfectly distinct. After a few trials, the true place for viewing the image may be ascertained with tolerable accuracy; and it will continue distinctly perceptible when the observer moves a short distance backward or forward from the proper position: but advancing beyond it, the image will soon begin to appear indistinct, and this indistinctness will increase till he arrives so near the mirror as its centre of concavity, where the image will be lost in confusion. If he still advances, another image in an upright position gradually becomes visible, as explained in the preceding case.

CCXLIV. The most singular and curious effects of concave mirrors, are those resulting from the position of objects at a greater distance from the mirror than its centre of concavity, as in the case above described, (242,) when a diminished and inverted image will be formed in the air between the object and the mirror. In order that this may be seen to the utmost advantage, particular situations must be assigned both to the object and the observer, which will be regulated by the concavity of the mirror and its consequent focal distance

Illustration 1. For the exhibition of such phenomena, however, spherical concave mirrors are not so well adapted as those of an elliptical figure, for the latter having double foci, any object placed in one focus of an elliptic concave mirror will form an accurate image in the other focus.

Fig. 139.



2. The above figure exhibits a convenient mode of arrangement for pro-

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CCXLIV. Which case of reflection by concave mirrors produces the most interesting phenomena? What form of concavity ought the mirrors to possess for the exhibition of these phenomena? Describe the arrangement of apparatus for exhibiting aerial images.

..ucing optical images in the air by means of a single mirror. Suppose C D to be one side of a room, or a screen dividing one part of the room from another, and having in it a square aperture E F, the centre of which may be about five feet above the floor. This opening may be surrounded with a black border, or a gilt moulding, so as to resemble a picture-frame. A large concave (elliptical) mirror, M N, is then to be placed in an adjoining apartment, so that when any object is placed at A, in one focus of the mirror, a distinct image of it may be formed in the other focus at B, or in the centre of the aperture E F. This image will be inverted with respect to the position of the object; therefore if a small statue, bust, or plaster cast of any object be placed upside down at A, an observer in the apartment at O will behold an erect image of the object at B. In order to give the greater effect to this exhibition, the object should be white, or at least of a very bright colour, and should be strongly illuminated by a powerful lamp, the rays of which must be prevented from reaching the opening E F.

3. In this case, the image being formed, not in the single focus of a spherical concave mirror, but in one of the foci of an elliptical mirror, it will not be confused or reduced; but will be rather larger than the object. When the image appears in the air, as here described, it will be distinctly visible only from the point O, and a person placed at a little distance, on either side, will see nothing of it. If, however, the opening E F be filled with smoke, rising from burning frankincense or other perfumes, the cloudy vapour will serve as a screen to receive the reflected image, which may thus be rendered visible to persons within the room O.

THE ORGANS OF VISION.

CCXLV. The eyes of animals bear a certain analogy to the optical instrument called a camera obscura; for the images of external objects within the sphere of vision, are actually formed or traced within the eye, in the manner that will be subsequently described.

CCXLVI. In man and other animals destined to inhabit the surface of the earth, the eyeball is a mass nearly spherical, but somewhat flattened in front. Those animals that dwell in the water have eyes very much flattened, the eyeball in most fishes forming but half a sphere, and in the *ray* species, it is but one quarter of the thickness of a sphere. In those birds that soar to the higher regions of the atmosphere, the anterior part of the eye is sometimes flat, and sometimes in the figure of a truncated cone;

Will the images in this case be direct or inverted? What will be the size and position of the image with regard to that of the object? CCXLV. To what is the construction of the eye analogous? CCXLVI. What relative sphericity have the eyes of land and of aquatic animals? What peculiarity is found in the eyes of birds that soar to great heights?

the upper part forming a short cylinder, surmounted by a very convex eminence.

CCXLVII. The eyes of spiders, scorpions, &c., are merely very minute points, which it would be very difficult to recognise as organs of vision, if their functions had not been demonstrated by precise experiments. Millepedes, flies, &c., have eyes often very large in proportion to the bulk of the insect, and composed of a multitude of small facets, or plano-convex lenses united into a hemispherical form, with their axes directed to a common focus. Many insects have, at the same time, simple and compound eyes; this is the case with wasps, grasshoppers, and some others. There exist likewise multitudes of animals, in which no organ of vision can be discovered; but it appears, that in such the sense of feeling is extremely delicate, and therefore supplies the defect of the other senses.

CCXLVIII. In the following descriptive notices of the organs of vision, and the phenomena depending on them, our attention will be restricted to the structure and functions of the human eye. But the eyes of some quadrupeds, as the ox or the sheep, so far resemble those of man, that sufficiently accurate ideas of the essential parts of the eye may be obtained by dissecting and examining an eye of either of those animals, and comparing its mechanism with the ensuing description.

Fig. 140.

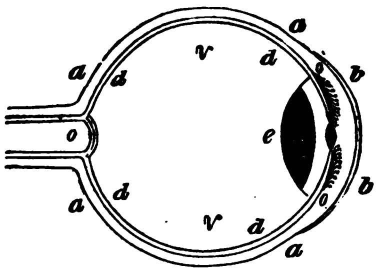
Illustration 1. The above figure exhibits a front view of the eye, or the anterior portion of the eyeball. The white part surrounding the centre is called the sclerotic* coat (*tunica sclerotica*,) *a a*, and it is continued within

* From the Greek Σκληρος, hard, firm; or Σκληροτης, hardness.

CCXLVII. What is said of the eyes of spiders and scorpions?

the orbit, round the back part of the eyeball, being formed of a dense membrane, which includes, as in a bag, the other parts of the eye. This membrane is perfectly opaque, and therefore is not continued over the front of the eye, but joins the transparent cornea,† *b*, which differs from it chiefly in being completely pervious to light, and therefore serves like a window to admit it to the interior of the eye for the formation of images. Within or behind the cornea may be perceived the iris,‡ *c*, a sort of coloured fringe, usually either of a dark brown or a grayish blue tint; and hence the distinction between black, and biue or gray eyes: but there are persons with extremely light complexions and white hair, (Albinoes,) who have red eyes, the iris being red, as in the eyes of a white rabbit. In the centre of the eye, surrounded by the iris, is a dark circular space of variable dimensions, called the pupil, *d*, through which the rays of light pass into the chambers of the eye

Fig. 141.



2. Fig. 141, is a vertical section of the human eye. Its form is nearly globular, with a slight projection or elongation in front. Its coats, or membranes as before mentioned, are the *sclerotic*, the *cornea*, the *choroid*, and the *retina*. It has two fluids confined within these membranes, called the *aqueous*, and the *vitreous* humours, and one lens, called the *crystalline*. The sclerotic coat is the outer and strongest membrane, and its anterior part is well known as the *white* of the eye. This coat is marked in the figure *a*, *a*, *a*, *a*. It is joined to the cornea, *b*, *b*, which is the transparent meme brane in front of the eye, through which we see. The choroid coat is a thin delicate membrane, which lines the sclerotic coat on the inside. On the inside of this lies the *retina*, *d*, *d*, *d*, *d*, which is the innermost coat of all, and is an expansion, or continuation of the optic nerve *o*. This expansion of the optic nerve is the immediate seat of vision. The iris *o*, *o*, is seen through the cornea, and is a thin membrane, or curtain, of different colours in different persons, and therefore gives colour to the eyes. In black-eyed persons it is black, in blue-eyed persons it is blue, &c. Through the iris, is a circular opening, called the *pupil*, which expands or enlarges when the light is faint,

* From the Latin *corneus*, horny, or like horn.
† So called from its being like the rainbow (*iris*) variously coloured.

What is the form of the human eye? How many coats, or membranes, has the eye? What are they called? How many fluids has the eye, and what are they called? What is the lens of the eye called? What coat forms the white of the eye? Describe where the several coats and humours are situated? What is the iris? What is the retina? Where is the sense of vision?

and contracts when it is too strong. The space between the iris and the cornea is called the *anterior chamber* of the eye, and is filled with the *aqueous* humour, so called from its resemblance to water. Behind the pupil and iris is situated the crystalline lens *e* which is a firm and perfectly transparent body, through which the rays of light pass from the pupil to the retina. Behind the lens is situated the *posterior chamber* of the eye, which is filled with the *vitreous humour*, *v*, *v*. This humour occupies much the largest portion of the whole eye, and on it depends the permanency and shape of the whole organ.

CCXLIX. Objects are seen in consequence of the images' being painted on the nerves, or *retina*, at the back of the eye; and though the images are inverted, yet the objects appear erect.

Experiment. Take off the *sclerotica* from the back part of the eye of an ox, or other animal, and place the eye in the hole of the window-shutter in a dark room, with its fore part towards the external objects; a person in the room will, through the transparent coat, see the inverted image painted upon the *retina*.

Observation 1. It is found from experience, that when the image upon the retina is bright, the object is clearly seen; and when the image is faint, the object appears faint; also, that when the image is distinct, the object is seen distinctly; and when the image is confused, the object appears confused. Hence it may be concluded, that these images are the cause of vision.

2. It is manifest, that a different conformation of the eye, or some parts of the eye, is necessary for distinct vision at different distances. Some think the change is in the length of the eye; others, that it is a change in the figure or position of the crystalline humour; and others, that it is a change in the cornea; but any of these changes would produce the effect.

CCL. Dimness of sight generally attends old people, and arises from the eye becoming too flat, and not uniting the rays exactly on the retina; or it may arise from the humours losing their transparency in some degree, which makes every object appear faint and indistinct.

CCLI. If the crystalline humour has either too much or too little convexity, the sight will be defective, owing to the image being formed before or behind the retina.

Observation. In *myopes*, or persons who are short-sighted, the humours of the eye are too convex, and bring the rays to a focus, before they reach the retina, unless the object be brought near to it; in which case, the image is cast farther back. In others, the humours of the eye have so little convexity, that the focal point lies behind the *retina;* whence, unless the object is removed to a greater distance from the eye, the vision will be indistinct. Such persons are called *Presbytæ*.

CCXLIX. How is it proved that the images of objects are represented or painted on the retina in an inverted position? In what way can it be proved that the images upon the retina are the cause of vision? CCL. What is the cause of dimness of sight in old age? CCLI. What peculiarity or defect of the eye causes persons to be short-sighted?

CCLII. When the diameter of an object is given, its apparent diameter is inversely as its distance from the eye.

Observation 1. The angle subtended as the least visible object, called by the writers on optics, the *Minimum Visible*, cannot be accurately ascertained, as it depends upon the colour of the object, and the ground upon which it is seen; it depends also upon the eye. To the generality of eye, the nearest distance of distinct vision, is about 7 or 8 inches. Taking 8 inches for that distance, and 2 for the least visible angle, a globular object of less than the three-hundreth part of an inch cannot be seen.

2. The apparent diameter of an object is as the diameter of its image upon the retina; and the diameter of the image, when the object is given, is *inversely* as the distance of the object; therefore the apparent diameter of the object is also *inversely* as the distance of the object. The same may be proved of any apparent length whatsoever.

3. Hence the apparent diameter of an object may be magnified in any proportion; for the *less* the distance of the eye from the object, the greater will be its apparent diameter. But without the help of glasses, an object brought nearer the eye than about five inches, though it appears larger, will at the same time appear confused.

4. Many deceptions in vision arise from the above consideration. We judge of the *distance* of any object by the visible length of the plane, which lies between the eye and the object. When this method fails us, we compare the known magnitude of the object with its present apparent magnitude; or we compare the degrees of distinctness with which we see the several parts of an object; or we observe whether the change of the apparent place of an object when viewed from different stations, or its *parallax* be great or small, this change being always in proportion to the distance of the object. On this principle, we may judge of the distance of a near object, by observing the change which is made in its apparent situation, upon viewing it successively with each eye singly. Or, since it is the difference of the apparent place of an object, as viewed by each eye separately which makes an object to be seen double, unless we turn both eyes directly towards it, and since in doing this, where the distance is very small, we turn the eyes very much towards each other, and less at a greater distance; the different sensations accompanying the different degrees in which the eyes are turned towards each other, afford by habit, a rule for judging of the distance.

5. In objects placed at such distances as we are used to, and can readily allow for, we know by experience, how much an increase of distance will diminish their apparent *magnitude*, and therefore, instantly conceive their real magnitude, and neglecting the apparent, suppose them of the size they would appear if they were less remote; but this can only be done, where we are well acquainted with the real magnitude of the object; in all other cases, we judge of magnitudes by the angle which the object subtends at the known or supposed distance; that is, we infer the real magnitude from the apparent magnitude in comparison with the distance of the object.

CCLIII. Optical illusions frequently occur in consequence of bodies in motion. If a sphere revolving

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CCLII. What is the proportion between the apparent diameter of an object and its distance from the eye? CCLIII. How may a circle be mistaken for a straight line?

on its axis be placed at a distance, it will be impossible to perceive the movement, unless there are on its surface spots or visible irregularities, the alternate appearance and disappearance of which may be observed; and it is thus only that astronomers have been enabled to ascertain the rotation of the sun and the planets, by observing spots on their surfaces.

CCLIV. A lighted candle or torch whirled in a circle, the plane of which passes through the eye, at a great distance, merely appears to come and go in a line, from one extremity to the other of the diameter of the circle. The visible paths of the planets through the heavens, in their revolutions round the sun, thus have the appearance of right lines, from one extremity to the other of which each luminary seems, to a spectator on the earth, alternately to advance and return.

CCLV. The impression of light on the eye is not merely instantaneous, but continues during a certain time after the luminous or illuminated object has been withdrawn. From the experiments of D'Arcy, it has been ascertained that the effect of light on the retina remains about 1-7 or 1-8 of a second after the light has actually been removed.* To this cause is to be ascribed the circle of light formed by whirling round a burning stick, a phenomenon with which every one must be acquainted. And on the same principle is constructed the amusing toy called the Thaumatrope,† contrived by Dr. Paris.

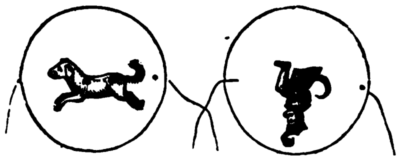
It consists of a number of circular cards, having silk strings attached to their opposite edges, as represented in the following figures. By these strings, one of the cards

* See a paper "On the Duration of the Sensation of Sight," in Memoires de l'Académie des Sciences, a Paris. 1765, p. 439.
† From the Greek θαυμα, a wonder, and τρεπω to turn.

CCLIV. With what example of this does astronomy furnish us? CCLV. Does the image of an object vanish from the eye the moment the object is withdrawn? For what length of time has D'Arcy found impressions to remain on the visual organ? What familiar and amusing experiments owe their interest to the durability of visible impressions? Describe the thaumatrope.

being twirled round with a certain velocity, both sides of it will be visible at the same time, and any objects traced on them, as a dog on one side and a monkey on the other, may be perceived simultaneously. Hence the parts of the picture being united, when it is whirled round, the monkey will be seen seated on the back of the dog. In this case the revolving card becomes virtually transparent, so that the objects on opposite sides of it may be viewed together nearly as they would be, if painted on the two surfaces of a plate of glass.

Fig. 142.



CCLVI. Another curious machine has been recently invented called the *Phantasmascope*,* the effect of which farther illustrates our perception of objects for a certain time after the objects themselves have been withdrawn.

Illustration 1. In this apparatus as modified by Professor Faraday, figures are seen through revolving wheels, or circular disks of pasteboard, with deep narrow notches at the edges. If a transparent star highly illuminated be placed behind a disk of pasteboard, or blackened tinplate with a single narrow opening extending from the circumference to the centre, it will necessarily hide the whole of the star, except that immediately opposite the openings; but if the disk be made to revolve rapidly, the whole star will be made visible; as may easily be conceived from previous remarks on the duration of impressions.

2. In the phantasmascope the pasteboard disks are painted with a variety of figures, in different positions, and the borders of the disks being cut into cogs or teeth, leaving openings between them, when made to revolve on a spindle, on looking at the objects as exhibited in a mirror, through the openning, they will display the most diversified and grotesque attitudes.

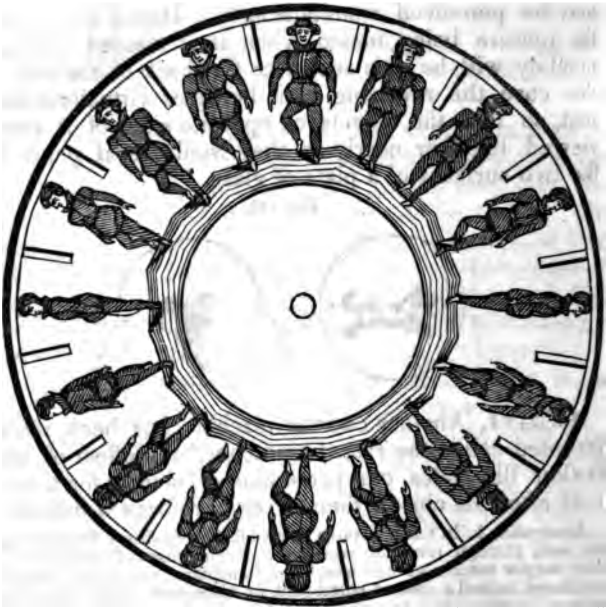
3. Thus the figures given in the following cut, when properly viewed, would all appear to be pirouetting like so many opera-dancers. By different arrangements of the openings, and varied designs, may be exhibited, in a

* From the Greek φανταсμα, a spectacle, and σκοπεω, to view.

CCLVI. Illustrate the phantasmascope. For what purpose is the mirror introduced in the exhibition of the phantasmascope?

similar manner, yawning figures, jumping frogs, creeping serpents, and a multiplicity of other strange combinations.

Fig. 143.



CCLVII. One of the most curious facts relating to the faculty of vision is the absolute insensibility to the impression of light at a certain point of the retina, so that the image of any object falling on that point would be invisible. When we look with the right eye this point will be about 15 deg. to the right of the object observed, or to the right of the axis of the eye, or the point of most distinct vision. When looking with the left eye the point will be as far to the left. The point in question, is the basis of the optic nerve; and its insensibility to light was first noticed by M. Marriotte, the French philosopher.

CCLVII. Are all the parts of the retina equally sensible to the impressions of light?

Experiment. This remarkable phenomenon may be experimentally proved by placing on a sheet of writing paper at the distance of three inches apart, two coloured wafers, then on looking at the left hand wafer with the right eye at the distance of about a foot, keeping the eye straight above the wafer, and both eyes parallel with the line which joins the wafers; on closing the left eye, the right hand wafer will become invisible; and a similar effect will take place if we close the right eye and look with the left.

CHROMATICS, OR THE THEORY OF COLOURS.

CCLVIII. The phenomenon of colours is one of the most curious of all the properties of light. In popular opinion, colours are considered as inherent properties of the substances on which they occur. Thus we hear it said by the uninformed that the redness of brick, and the greenness of grass are properties as peculiar to those substances as the shapes they assume; this, however, is an error.

CCLIX. The essential cause of colour is light; but it depends also on the texture of the surface coloured.

CCLX. There are seven different colours, which are denominated *primary*, these are red, orange, yellow, green, blue, indigo, and violet.

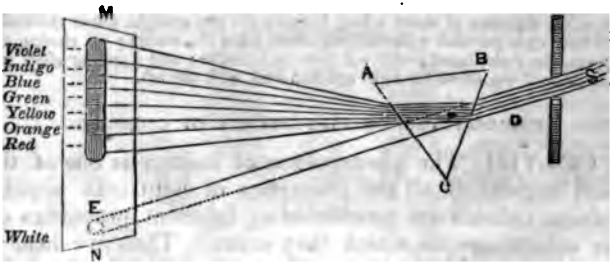
CCLXI. The discovery of the compound nature of light, was made by Sir Isaac Newton, in the following manner:—

Illustration 1. Let a bundle of rays proceeding from the sun S, be admitted through the window shutter of a darkened room as represented in the figure, page 142, and allowed to fall on the triangular piece of glass A B C, called the prism. A ray D thus entering, and suffered to pass unobstructed, would form on a plane surface a circular disk of white light E, but the prism being so placed that the ray may enter and quit it at equal angles, it will be refracted in such a manner, as to form on a screen M N, properly placed, an oblong image called the solar spectrum, and divided horizontally into seven coloured spaces, or bands of unequal extent, succeeding each other in the order represented: *red, orange, yellow, green, blue, indigo, violet.*

2. These bands are not separated by distinct lines, so that it is difficult to determine where one ends and another commences, the several tints at their borders being blended, and each almost imperceptibly united with those next to it; the whole spectrum exhibiting the seven principal colours, with intermediate shades or mixtures.

CCLXI. By whom, and by what experiment was the compound nature of light made known? How is the separation of white light into its constituent coloured rays most advantageously displayed? What is the image of a beam of light refracted by a prism usually denominated? Into how many, and what spaces is the solar spectrum divided? What are the two extremes of the spectrum?

Fig. 144.



Observation 1. It will be seen by the above figure, that all the rays are somewhat bent out of their course the violet, the most, and the red the least.

2. The rectangular screen M N, on which is received the different rays, is called the *spectrum*.

Experiment 1. The following experiment is often cited as evidence of there being seven primary colours, namely, that if the different prismatic coloured rays be allowed to pass though a double convex lens they become white-light.

2. The same effect is produced by mixing in the proper proportions seven different coloured powders; or still better, by painting the seven colours on a circular board, in the proportions occupied by these several colours in the spectrum, and whirling the board very rapidly.

CCLXII. The prismatic colours are seen in spray that rises from waterfalls, cascades, fountains, dew on the grass, glass ornaments, about chandeliers, rainbows, &c.

The colours of the rainbow are also often seen in the refraction of light through a tumbler of water, standing in the sun. In all these cases, the back of the observer must be turned towards the sun. It is owing probably to the same principle, that we often see clouds decked in the most gorgeous colours.

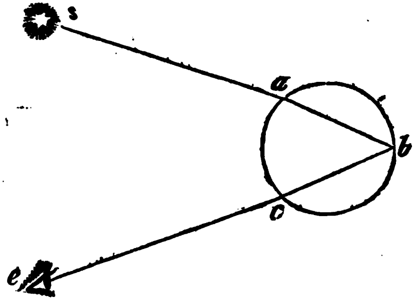
CCLXIII. The rainbow is a phenomenon produced by the refraction and reflection of light by the drops of falling rain, and can only be seen when the sun is in the part of the heavens opposite the rainbow.

Which colour is refracted most, and which least? When the several prismatic colours are blended, what colour is the result? When the solar spectrum is made to pass through a lens, what is the colour of the focus? CCLXII. By what other means beside the prism, can the rays of light be decomposed? CCLXIII. Describe the rainbow.

CCLXIV. Rainbows are single or double. The following illustration represents the single rainbow which is produced by two refractions, and one reflection.

Illustration. While the sun is shining upon the falling drops of rain, all those rays that enter the drop near the edge as at *a*, fig. 145, are refracted and reach the back part of the drop at *b*, where, instead of being transmitted and passing out of the drop, are reflected in the direction *b c*, and on arriving at *c*, are again refracted and reach the eye of the spectator at *e*, where each of the colours being differently refracted and separated from each other all the colours of the rainbow are exhibited.

Fig. 145.



CCLXV. The double rainbow is represented in the form of a double arch, one within the other—the outer bow is always fainter than the inner, and has also its order of colours reversed; it also requires two reflections and two refractions.

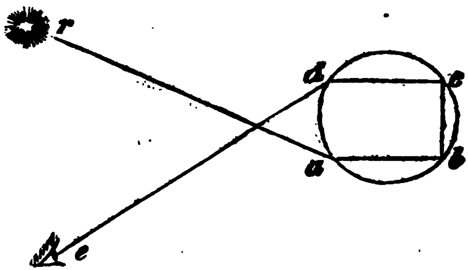
Illustration. Fig. 146, illustrates the case where a double rainbow is seen, and describes the track of the ray, in what is called the secondary bow, where the ray *r* enters the drop at *a*, and is refracted in the line *a b*, and at *b* it is first reflected and moves in the direction *b c*, and again reflected at *c* in the line *c d*, until it arrives at *d*, where it suffers another refraction and emerges from the drop, and reaches the eye of the spectator at *e*.

Observation 1. The colours of the secondary rainbow are paler than those of the primary, because some of the light is lost in the extra reflection of the former.

CCLXIV. What are the kinds of rainbow? Illustrate the single rainbow. CCLXV. Define the double rainbow. Illustrate it by the diagram. Why is the secondary rainbow fainter?

2. The rainbow assumes the form of a semicircle, because it is only at certain angles that the refracted rays are visible to the eye.

Fig. 146.



CCLXVI. The colour of all bodies depends as before stated on some peculiar property of their surfaces causing them to absorb some of the coloured rays and reflect others.

CCLXVII. All bodies have the colour of those rays which are reflected from them, while all the other rays are absorbed.

Illustration 1. Thus on every body illuminated by the rays of the sun, the whole seven primary rays are supposed to fall.

2. The grass and other vegetables are green, because the green rays only are reflected, and all the rest are absorbed; and the same remark applies to all other coloured surfaces.

3. In black all the rays are absorbed; and in white, they are all reflected; white and black are therefore not strictly colours, though in popular language, they are often so called.

CCLXVIII. *Double refraction* is the property exhibited by some transparent bodies, of forming a double image of any object seen through them. A peculiar kind of crystalline limestone called Iceland spar, is one of the most celebrated minerals for exhibiting a double refraction.

Fig. 147.

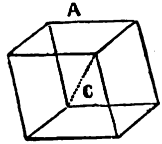
Why it does assume the semicircle? CCLXVI. On what does the colour of bodies depend? CCLXVII. How can you explain the different colour of different bodies? Give the first, second and third illustrations. CCLXVIII. Define double refraction.

Illustration 1. This mode of refraction may be experimentally demonstrated by means of a small plate of Iceland spar, or crystallized carbonate of lime, not more than ¼ of an inch in thickness. If a plate of glass be placed over either or all the preceding figures, A, B, C, D, each will appear singly, as to the naked eye; but if a plate of Iceland spar be held above one of the figures, a double image will be perceived, as two dots, two circles, or two lines instead of one.

2. The distance between the two images will depend on the thickness of the plate of spar. If it be ¼ of an inch thick, the images will be so near together that the little circle B will look like a figure of 8. There is, however, another circumstance which will influence the relative separation of the images; and that is the position of the plate; for if it be laid flat on the paper and slowly turned round horizontally, one of the images will be perceived to revolve round the other; so that the circle will in one position appear thus 8, and in another thus ∞; and the lines will coalesce and diverge successively, as the plate is made to revolve.

3. In explanation of this phenomenon it may be stated that a ray of light on entering into the transparent spar becomes divided into two portions, one of which follows the ordinary law of refraction, while the other undergoes a separate refraction, according to a new and extraordinary law. The Iceland spar consists of rhomboidal crystals, masses of which are always reducible by natural cleavage into exact rhomboids. These are the forms of the molecules into which the mass can be separated by continued subdivision; and in every one of these rhomboids the short diagonal is called the optical axis.

Fig. 148.



4. Thus in the above figure the diagonal line C represents the axis of the rhomboidal solid A B. Now if a ray of light is transmitted through a crystal in the line of its optical axis no double image will be formed, and the ray will be refracted simply according to the ordinary law of the proportional sines; for in this case the ordinary and extraordinary rays, as they have been termed, will coincide. But in all other cases the law is essentially different, the ray becoming divided, and one part of the pencil will be refracted, according to a law of a very singular and complicated nature.

OPTICAL INSTRUMENTS.

CCLXIX. *Spectacles* are instruments used to aid imperfect sight. They have been used since the latter part of the 13th century; but the magnifying properties of

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Give the first illustration. What circumstance determines the amount of separation? What is the explanation in third illustration? What is the form of the crystal of iceland spar? What is the optical axis of such a crystal? CCLXIX. Define spectacles, and give their history.

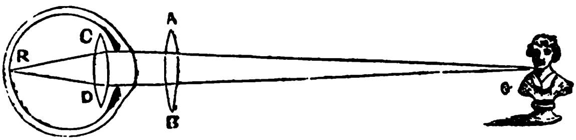
convex lenses or other transparent bodies was known at a much earlier period, though we are not informed of the precise manner in which they were used.

CCLXX. There are two distinct kinds of spectacles, those with convex glasses which magnify objects seen through them; and those with concave glasses which diminish objects.

CCLXXI. In old persons the transparent cornea becomes flattened, and possibly also the crystalline lens; consequently the rays of light from distant objects do not converge to a focus so as to form a distinct image on the retina—unless the objects are at a considerable distance from the eye.

Illustration 1. Thus it happens that old people who attempt to read without the aid of spectacles, are obliged to hold the book at arm's length. The manner in which they are aided by spectacles may be illustrated by examining the accompanying woodcut, fig. 149.

Fig. 149.



2. Let C D be supposed to represent a section of the crystalline lens, and A B a similar section of a spectacle lens. Then the object O, at six inches from the eye will form a perfect image on the retina, at R; but if the latter lens be removed, the object at the same distance will appear confused, and in order to appear distinct must be withdrawn three or four times that distance, and if it be very minute, the unassisted eye cannot see it distinctly at any distance.

CCLXXII. Short, or near-sighted persons have the transparent cornea too prominent, in consequence of which the rays of light from objects are conveyed to a focus, before they reach the retina, unless the object be brought near the eye.

Illustration 1. Where this peculiarity of vision exists but in a slight de-

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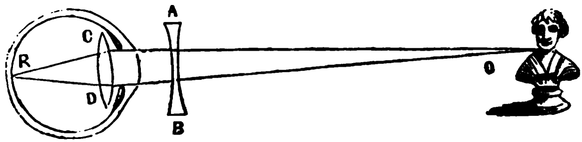
CCLXX. How many kinds of spectacles, and what are they? CCLXXI. What is the defect in the sight of old people? Illustrate by the diagram the aid afforded by convex spectacles. CCLXXII. What is the defect of short-sighted people, and what advantages have such persons?

gree, it is rather an advantage than otherwise, as the individuals are thus gifted with a kind of microscopic sight; for they can see smaller objects than are commonly discerned by others, and are merely obliged to hold them relatively nearer to the eye. Distant objects, however, can only be seen confusedly; and hence the advantage such persons derive from concave spectacles. The nature of the assistance which these glasses afford will appear from considering the following diagram.

Fig. 150.



2. Let C D, as before, represent a section of the crystalline lens, then the rays from the object O will be rendered somewhat divergent in their passage through the concave glass A B, so that the effect of the prominent cornea on them will be diminished, and they will form a perfect image at R; whereas if the concave glass were removed, the rays would come to a focus before they reached the retina, and diverging again, the image would be confused.

CCLXXIII. Microscopes are instruments for magnifying small objects, and are of two kinds, *Single* and *Compound*.

CCLXXIV. The single microscope consists of a double convex lens—such is the common sun-glass; the glasses of spectacles for old people, the glasses used by watchmakers for examining fine work.

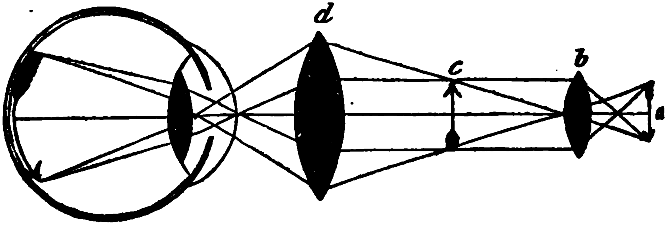
CCLXXV. The compound microscope consists essentially of two convex lenses, the one towards the objects, called the object-glass; that towards the eye, called the eye-glass. The lenses are generally closed in a tube for the purpose of convenience.

Illustration. The position of the glasses will be readily understood by inspecting the woodcut, fig. 151, on the following page.

The object *a* is placed a little beyond the object-glass *b*, and an inverted image formed at *c*, which as the rays proceed to *d*, is magnified and after passing though the lens *d*, it is again inverted, where the rays cross each other near the eye and is painted on the retina.

Illustrate the use of concave spectacles by the diagram, fig. 150. CCLXXIII. What are microscopes, and how many kinds? CCLXXIV. Define the single. CCLXXV. Define the compound, and illustrate by the diagram.

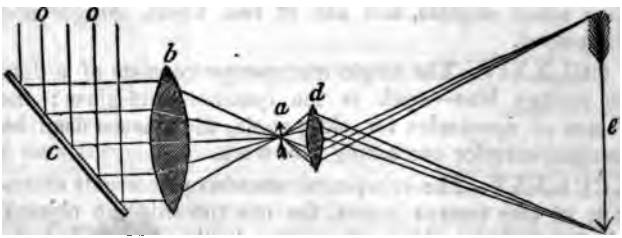
Fig. 151.



CCLXXVI. The *Solar microscope* depends on the sunshine, and is used in a darkened room. It consists of a moveable mirror, a large double convex lens, and a small one.

Illustration. The form of the parts and their relative position may be understood by inspecting the figure below, where *c* represents the moveable mirror to receive the rays of the sun, *oo*; *b* is the large double convex lens to condense the rays to a focus at *a*, and *d* the small double convex lens to magnify the image which falls on a large white screen at *e*.

Fig. 152.



CCLXXVII. *Telescopes* are instruments for viewing distant objects, and are of two kinds, *Refracting* and *Reflecting*.

CCLXXVIII. In the first kind the image of the object is seen with the eye directed towards it, and in the second, the image is seen reflected from a mirror.

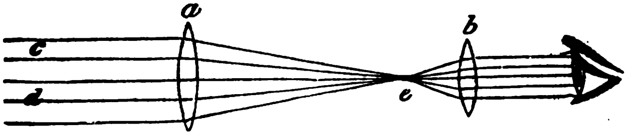
CCLXXIX. The most simple refracting telescope con-

CCLXXVI. Define the solar microscope. Illustrate it by fig. 152. CCLXXVII. Define what is meant by the telescope, and the kinds used. CCLXXVIII. Define each kind. CCLXXIX. Define the refracting telescope, and illustrate by the diagram.

sists essentially of two convex lenses, one towards the object and called the object-glass, the other next the eye called the eye-glass. The distance of the lenses from each other must be such that their foci will meet in the same point: or in other words the distance must be equal to the sum of their focal distances.

Illustration. See the woodcut below.

Fig. 153.



The above figure represents the glasses of the telescope without the tube, which though generally used is not a necessary appendage to the instrument.

To explain further the principles of the telescope; let the focus of the object-glass *a*, in the last figure, be 8 inches, and that of the eye-glass *b*, be 2, then the sums of their foci will be 10 inches, therefore the two lenses must be placed 10 inches apart.

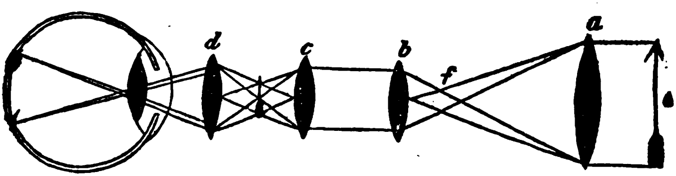
To illustrate this subject still farther, let *c d*, &c., represent the rays from some distant object as the moon, then the image formed by the object-glass *a*, and seen through the eye-glass *b*, will have its apparent diameter very much magnified.

With such a telescope the image will, with respect to the object, be inverted, but in viewing celestial objects, this circumstance is a matter of no consequence.

CCLXXX. The *Terrestrial telescope* is used to view objects on the earth in an erect position, and consists of an object-glass, and three eye-glasses.

Illustration. The manner in which the object is made to appear erect, and in which the rays are brought to a focus, may be learned from the figure below.

Fig. 154.



CCLXXX. What is the difference between the astronomical and the terrestrial telescope? Describe the terrestrial telescope. Illustrate it by the diagram.

The diagram, fig. 154, represents the terrestrial telescope, consisting of an object-glass and three eye-glasses as *a*, *b*, *c*, & *d*—the object of the two additional eye-glasses is to cause the object to appear erect, but they do not alter its apparent diameter. All the glasses are placed at the sum of their focal distances from each other, as may be seen by inspecting the figure, and the course of the rays may also be seen, by tracing the lines in the diagram, where *o* represents the object, and the rays coming from it are refracted by the lens *a*, and converged to a focus at *f*, where they cross each other, and passing through the lens *b*, are rendered parallel; passing through *c*, they again cross each other, as seen by the lines of the diagram and the position of the arrow; and by passing through the lens *d*, they are rendered more nearly parallel, in which state they enter the eye on the retina, of which the image is painted inverted but making the object appear erect.

Observation. The common spy-glass is an instrument of this kind. Those of the best manufacture, will enable one to see distinctly the satellites of Jupiter, and will for most purposes answer as a substitute for the telescope. To ascertain the comparative value of a telescope, place a paragraph of a newspaper or other fine print, and measure the distance required to read it, by the instrument to be tried, and compare with a standard instrument.

CCLXXXI. The magnifying power of the reflecting telescope is found by dividing the focal distance of the object-glass by the focal distance of one of the eye-glasses.

CCLXXXII. The common reflecting telescope consists of two reflectors, and one or more convex eye-glasses.

Fig. 155.

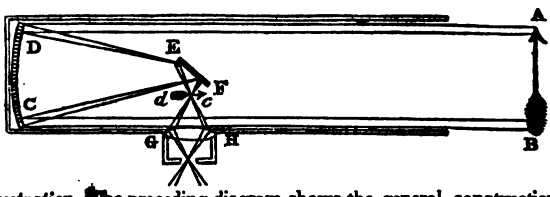


Illustration. The preceding diagram shows the general construction and effect of the Newtonian reflecting telescope, in which the concave metallic speculum C D receiving the rays issuing from the object A B, which it renders convergent, and thus forms a reversed image in the plane mirror E F, inclined at an angle of 45 degrees; and this image being reflected to *d c*, at the focus of the lens or eye-glass G H, is seen through the aperture before it by the observer.

Observation. In the original or Gregorian telescope, the image is viewed by looking towards the object, as in the refracting telescope; and there are other modifications of this instrument, as those of Cassegrain and Herschel, which need not be introduced in so short and general a treatise, as the present work is intended to be.

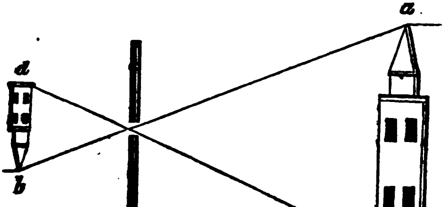
CCLXXXI. How is the magnifying power of the refracting telescope ascertained CCLXXXII. Describe the reflecting telescope. Give the illustration and observation.

CCLXXXIII. *Camera Obscura.* This instrument consists of a darkened room supplied with a screen, and having an aperture in its side or top for receiving the rays of light from without.

Illustration. To make an experiment with this instrument, let a room be so close as to exclude the light, and from a small aperture allow the light to enter on one side; the image of external objects, such as trees, houses, people walking, will be seen in an inverted position on the walls opposite to the aperture.

Observation. The necessity of the inverted image will appear, when we recollect that light always moves in straight lines, and that these rays which come from the top of an object, as a house, or a tree, after passing through the aperture, will keep on in a straight line, and those rays from the bottom of the object, will, for the same reason, continue after passing the aperture, in a straight line, and in an upward direction; consequently, the rays must cross each other just after passing through the aperture. These observations will appear more intelligible by the diagram, fig. 156, where the ray *a*, after passing the aperture, constitutes the lowest part of the image *b*, while the lowest part of the object *c* becomes the highest in the image at *d*.

Fig. 156.



CCLXXXIV. The camera obscura, from the definiteness with which it represents objects, is often used by painters for taking landscapes and other views—in which case, the image is received on white paper, and its outlines traced with a pencil, and the body of the picture left to be filled up at leisure.

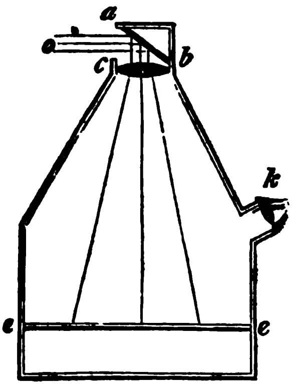
CCLXXXV. This machine is rendered portable and so fitted up as to be allowed to revolve on a centre.

Illustration. The revolving camera obscura is shown at fig. 157, where the line *a b*, represents the inclined reflector, capable of revolving with the

CCLXXXIII. Describe the camera obscura. Give the illustration. Why is the image of objects inverted? Explain by diagram. CCLXXXIV. What are the uses of this instrument? CCLXXXV. What modifications of the camera obscura? Illustrate the revolving camera obscura.

lens *c*; there is an opening on one side, where the rays *o* enter, and being reflected downward by the mirror, pass the lens *c*, and are received on the screen *e e*, which being of white paper the experimenter is enabled to trace the view by means of the opening *k* in the side.

Fig. 157.



CCLXXXVI. The *camera lucida* was invented by Dr. Wollaston, in 1807, for the purpose of delineating distant objects, and for copying or reducing drawings. This instrument consists of a quadrangular glass prism, by which the rays from an object are twice reflected.

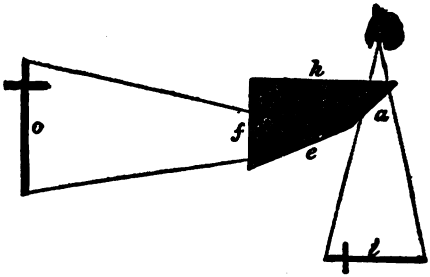
Illustration 1. Its form is shown in fig. 158. The object *o* to be traced is opposite the perpendicular surface of the prism *f*, and the rays proceeding from *o* pass through this surface, and fall on the inclined plane *e*, making an angle with *f* of $67\frac{1}{2}°$: from this they are reflected at an equal angle to the plane *a*, making an angle of 135° with *e*, and are again reflected to the eye above the horizontal plane, which makes an angle of $67\frac{1}{2}°$ with the last reflection. The rays of light from the objects proceeding upward from *a* towards the eye of the observer, the observer will be led to imagine the image at *i*, and by placing the paper below in this place, the image may be traced with a pencil.

2. In order to increase or diminish the size of the picture, the prism is mounted in a brass frame supported by brass tubes, capable of being drawn out or shortened at pleasure. The picture always bears the same relation in size to the object as the distance from the eye to the image or paper is to the distance from the object to the eye; hence by lengthening the tubes the drawing is increased in size: it should be remarked, that by this prism no real image is formed, but it always appears as far below the prism as the object is before it. The brass frame of the prism has usually two lenses, one

CCLXXXVI. Describe the camera lucida. Give the illustrations.

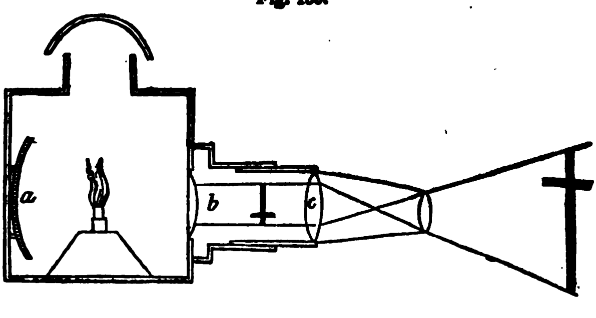
concave and the other convex, the former to be used in front at *f* for short-sighted persons, the latter above at *h* for long-sights.

Fig. 158.



CCLXXXVII. *The Magic Lantern.* As an amusing as well as instructive optical machine, there is hardly any superior to the magic lantern, invented by Father Kircher. It is composed, as shown in figure 159, of a square tin box, containing a lamp, behind which is placed a metallic concave reflector *a*; and in front of the lamp is a plano-convex lens *b*, which receives on its plane surface the reflected light of the lamp, and concentrates it on the object, which is magnified by another lens *c* fitted to the extremity of a tube projecting from the lantern. The objects are painted on thin plates of glass, which may be passed through a narrow opening in the tube between the two lenses. This

Fig. 159.



tube must be double, one end moving within the other, so that the tube carrying the outer lens may be drawn backward or forward, till the object is in the conjugate focus of that lens. Then if it be turned toward a vertical screen, a magnified image will be formed, as seen in the inverted cross; and the further the lantern is withdrawn from the screen, the larger will the object appear; but when the distance is considerable it becomes indistinct.

ELECTRICITY.

This subject will be treated under the following heads:—

Common Electricity,
Galvanic Electricity,
Magnetic Electricity.

COMMON ELECTRICITY.

CCLXXXVIII. Electricity is comparatively a modern science. The ancients, it is true, were acquainted with a few detached facts; they knew, for example, that amber (called in Greek electron) had the power of attracting and repelling light bodies, after it had been rubbed in contact with a piece of woollen or silk. The amber, in consequence of this remarkable property, was called an *electric*, and the phenomena presented by it were together called *electricity*. Afterward, other substances, having properties similar to amber, were discovered; among which are glass, rosin, sulphur, sealing-wax, &c., all of which were denominated *electrics*, and all those which could not be excited, were called *non-electrics*.

CCLXXXIX. Electricity is supposed to be a subtile fluid, somewhat like caloric in its nature; the earth and

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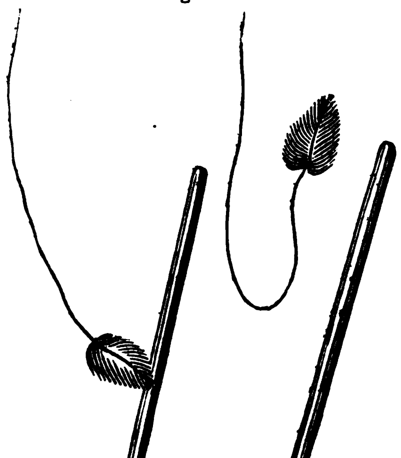
CCLXXXVIII. What knowledge had the ancients of electricity? What is said of amber? What is said of electrics and non-electrics? CCLXXXIX. Define electricity.

every body with which we are acquainted, contains a certain portion of it, which exists on the surface, and in a latent or concealed state, so that we are not aware of its presence, until we take some means of exciting it.

Illustration. Thus, if a glass tube be rubbed in contact with a silk handkerchief, it will attract light substances when brought near, such as small fragments of paper, cotton, gold-leaf, &c.; and if the knuckle be brought near the tube while in this state, a small spark will pass from the tube to the hand, accompanied with a snapping noise, and a sensation like the prick of a pin.

Experiment. Suspend a light feather by a piece of fine thread, and having excited the glass tube by means of silk, present it to the feather, which will be attracted, but on gently withdrawing and again bringing it near the feather, the latter will be steadily repelled, so that it will be impossible to approach it with the tube; after a while, however, it loses its repulsive power, and is again attracted and then repelled as before; these two states may be understood by inspecting the accompanying wood-cut:—

Fig. 160.



CCXC. It would be interesting to inquire, what takes place when we rub a piece of glass with a silk handkerchief? According to Dr. Franklin, the silk and glass, before being rubbed, contained an equal share of the elec-

Define the illustration and experiment. CCXC. Give the rationale according to Franklin's theory.

tric fluid, which was uniformly spread over the surface but when the two were rubbed in contact, the silk was robbed of a part of its electricity by the glass; hence the former has less than its natural share, and the latter more; if therefore, we present to the glass any body that has not been excited, it will receive from it its excess of electricity in the form of a spark, as proved by presenting the knuckle to the excited tube. But the silk may be made to exhibit the spark also after friction, by presenting it to an unexcited body; here, however, the spark passes from the body to the silk, because the latter being robbed of its fluid by the glass, has really less than it had at first, and will take it from any body that has its full natural share.

CCXCI. From the above remarks, it appears that electricity has a tendency to diffuse itself uniformly over the surfaces of all bodies. This is called its tendency to an equilibrium; and electrical experiments are nothing more than the different methods of disturbing this equilibrium, or, in other words, robbing one body of its electricity to give it to another.

Experiment 1. Excite the glass tube, (as in *Exp. Prop.* cclxxxix.,) and cause it to repel the feather; while in this state, rub a stick of sealing-wax or roll of sulphur, in contact with flannel or woollen cloth, and present it to the feather, it will be attracted and fly to it.

2. Now reverse the experiment, and having electrified the feather by the sealing-wax, bring the excited glass near it, and instead of being repelled, it will be attracted.

Observation 1. These experiments show that the electricity excited in the glass, differs from that excited in the sealing-wax, inasmuch as bodies repelled by the former, are attracted by the latter; and *vice versa.*

2. Hence bodies having the same kind of electricity, as was before shown, (cclxxxix.,) repel each other, while those having different kinds attract each other.

CCXCII. Du Fay, a French electrician, explained the above facts, by supposing there were two distinct electric fluids, one naturally belonging to the sealing-wax, resin, and all resinous bodies, and the other belonging to glass, and all vitrified or glassy bodies: the former was accordingly called *resinous* electricity, and the latter *vitreous;*

CCXCI. What is the tendency of electricity? Describe experiments 1 and 2. What do they prove? CCXCII. What is the inference from these experiments? CCXCII. How did Du Fay explain them?

but the terms *negative* and *positive* are more generally used at the present time; the former corresponds to the resinous, and the latter to the vitreous. The feather electrified by the excited *glass*, is said to be in a *positive state*, while that by the *sealing-wax* is *negative*.

CCXCIII If the glass when rubbed by the silk be positive, by robbing the silk of a portion of its electricity, the silk is necessarily rendered deficient or negative; hence we have developed another electrical law, which is, "that one kind of electricity cannot be produced without the other," and that when the body becomes positive, some part of the exciting arrangement must be as highly negative.

Illustration. When silk is rubbed with glass, the silk is negative and the glass positive; when flannel and sealing-wax are used, the former is positive, and the latter negative.

CCXCIV. There are a number of familiar instances of electrical phenomena.

Illustration 1. If the back of a cat be rubbed at night, especially in clear and cold weather, you will observe sparks, accompanied with a snapping noise and a pricking sensation in the hand, from the electricity developed by the *friction*.

2. Another familiar example is frequently noticed. When taking off clothing, and especially silk which has been worn next to the skin, sparks have been known to come from the silk, accompanied with a snapping noise. This is often seen in drawing off a silk stocking in cold and clear weather; in consequence of the silk becoming highly negative by the friction, a spark will pass from the foot to the silk to restore the equilibrium.

CCXCV. The most abundant natural source of electricity is in the atmosphere and earth, and is often exhibited in the form of lightning, during thunder-storms. This subject will be further noticed under the head of lightning.

CONDUCTORS AND NON-CONDUCTORS OF ELECTRICITY.

CCXCVI. Those bodies which allow the electric fluid to pervade their whole surface, when an electrified body is brought into contact, are called *conductors* of electricity,

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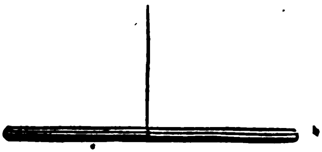
CCXCIII. What law is developed by rubbing glass and silk? Give the illustration. CCXCIV. What experiment is referred to with cat's fur? What experiment with a silk stocking is mentioned? CCXCV. What is said of the atmosphere? CCXCVI. Define conductors and non-conductors.

while those which will not transmit it beyond the point of contact, are called *non-conductors.*

Fig. 161.



Experiment. Suspend from the ceiling by a silk thread, a bar of metal as seen in the wood-cut, and in a similar manner suspend a glass tube or rod of similar dimensions; excite another glass tube and bring it in contact with one end of the metal, which will receive a slight spark, and on approaching the opposite end with a feather, or some other light body, it will be immediately attracted, showing that the electric fluid which had been communicated to one end of the bar, had traversed the whole length, by means of the conducting power of the metal. If we attempt the same experiment with the similarly constructed glass bar or rod, we shall find that the fluid communicated to one end of the tube, cannot be perceived by approaching the other with a feather, proving thereby that the glass will not conduct the electric fluid over its surface.

CCXCVII. The metals are by far the most perfect conductors; next to them, well-burnt charcoal and black lead; then strong acids, such as oil of vitriol, aquafortis, &c. Water, rarefied air, most vapours, earthy bodies, and metallic ores, are imperfect conductors.

CCXCVIII. Shellac is the most perfect non-conductor: sulphur, sealing-wax, resin and all resinous bodies, glass, raw and bleached silk, dry air and baked wood, are also non-conductors.

CCXCIX. Any body is said to be *insulated* when placed in such a situation as to be surrounded by non-conductors. Thus, the metallic bar in the experiment last described, which is in contact with nothing but silk and dry air, both non-conductors, is said to be insulated A person may be insulated by standing on a stool supported by glass legs.

Describe the experiment with metal and glass rod. CCXCVII. Describe the different conductors in their order of conducting power. CCXCVIII. Describe the non-conductors in the same manner. CCXCIX. What is understood by insulation?

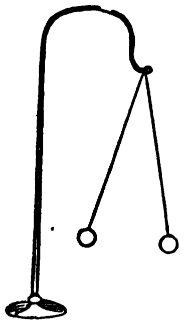
ELECTRICITY BY INDUCTION

CCC. When a glass tube is excited (as in the experiment under proposition ccxci.) and brought near a feather or other light body, the latter is thrown into an opposite electrical state; that is, if the tube be positive, the light body will be negative, and *vice versa*. The light substance thus excited, is said to be electrified by *induction*.

Observation. Electricity by induction is always produced when an excited body is brought near another body unexcited. The same effect is produced, if one side of a non-conductor receive one kind of electricity; the opposite side is thrown into the opposite state by induction. This will be further explained under the Leyden jar.

ELECTROMETERS.

Fig. 162.



CCCI. An electrometer is an instrument used for showing when a body is electrically excited. It is made in a variety of shapes; one of the most common is that represented in the accompanying wood-cut, in which a glass rod, bent in the proper form, and inserted into a wooden base, supports a couple of pith balls, which are suspended by delicate threads of white silk. When an excited body is presented, the balls will be first attracted; but acquiring the same degree of electricity as the excited body, they will soon be repelled as seen in the figure.

CCCII. One of the most useful, simple, and easily made, is constructed by suspending two very light and downy feathers by two threads of raw silk, from the ceiling, or some other convenient place. The threads should be at least four feet in length, and when unexcited will hang together, but on approaching them with an excited

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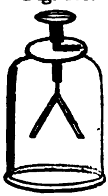
CCC. What is meant by electricity by induction? What observation illustrates the subject? CCCI. Define electrometers. CCCII. Describe the most simple construction.

glass tube, they will first be attracted, but both acquiring the same kind of electricity, they will soon be repelled.

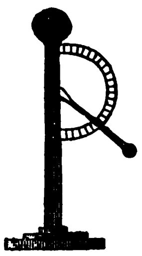
CCCIII. For still more delicate purposes, the gold-leaf electrometer of Bennet is substituted; it is generally enclosed in a glass jar, and consists of a brass cap and a connecting wire, which passes through the cover, and terminates in two strips of gold-leaf, as seen in the accompanying figure. I have seen the gold-leaves diverge, by bringing an excited glass tube within five or six feet of the brass cap.

Fig. 163.



CCCIV. There is a fourth kind of electrometer, called the quadrant electrometer, as seen in the wood-cut. The stem is made of wood, and the semicircle of ivory, the lower half of which is divided into ninety degrees; from the centre of the semicircle hangs a rod of light wood, with a knob of pith or cork at the end, to serve as an index.

Fig. 164.



If this electrometer be placed in contact with any body to be electrified, the index will rise as the electric fluid accumulates, until it point to ninety degrees, which indicates the greatest intensity of which the instrument is susceptible.

ELECTRICAL MACHINES.

CCCV. The electrical machine is made in a variety of forms, but there are two kinds in general use, the *cylinder* and *plate* machines.

Illustration. The figure 165 represents a glass cylinder C C, from 10 to 16 inches in diameter, and about twenty inches in length, supported so that it may turn on its axis, on two pillars of glass, fixed to a wooden stand. Two metallic conductors, P N, equal in length to the cylinder, and about one third of its diameter, are fixed parallel with it on either side, upon two glass pillars, which are cemented into two separate pieces of wood sliding in grooves,

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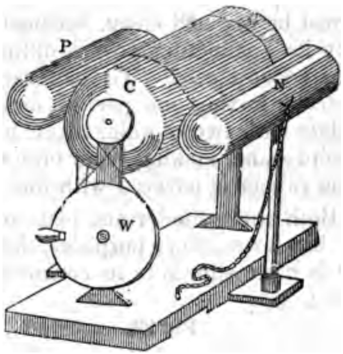
CCCIII. Describe Bennet's electrometer. CCCIV. Describe the quadrant electrometer. CCCV. Describe the electrical machine. Give the illustration of the cylinder machine.

so that they may be respectively adjusted at any distance from the cylinder required. To one of these conductors N, is attached a cushion, an inch and a half wide, and about as long as the cylinder, against which it may be made to press by means of a bent string; and to the upper part of it is sewed a flap of oiled silk, which extends loosely over the cylinder, to within an inch of a row of brass pins or pointed wires, proceeding from the side of the opposite conductor. The conductor to which the cushion is attached, is called the negative conductor; and the other, which by means of its points collects electricity from the glass, is named the positive conductor, and also the prime conductor. The cylinder may be made to revolve in the direction of the silk flap, simply by a winch fitted to it, or by a multiplying wheel W.

Fig. 165.



CCCVI. When it is requisite to obtain positive electricity, the cushion or negative conductor must be connected with the wooden stand of the machine, by a chain or wire, and thus the electric equilibrium of the rubber is restored by the earth, as fast as it is disturbed by the action of the machine; but the opposite positive conductor being insulated, cannot return to a state of equilibrium, except by the action of the wire. If it be required to produce electricity, the cushion must be insulated by removing the chain, and attaching it to the prime conductor P, whence the positive electricity will pass to the earth, and the conductor N will become negatively electrified.

CCCVII. The plate electrical machine, consists of a

CCCVI. What is the method of obtaining positive and negative electricity? CCCVII. Describe the plate machine.

flat plate of glass of the kind used in making looking-glasses; it is cut into a circular form, a hole is made through its centre, and an axis passes through it. It is then mounted on wooden pillars or framework, with the axis horizontal, like a common grindstone. The rubbers are fitted on each side of the plate, and the prime conductor near its circumference; this is used in the same manner as the cylinder machine.

CCCVIII. To put the electrical machine in good order, every part must be dry and clean, because dust or moisture would, by its conducting power, diffuse the electric fluid as fast as accumulated. To increase the effect an amalgam made by mixing one part of metallic antimony in a melted state with two of quicksilver, heated nearly to the boiling point—and making them into a stiff ointment with lard—the rubber is covered with this amalgam.

CCCIX. Both the cylinder and plate machines are in general use; but for ordinary purposes, the former is preferable; as it is more simple in its construction, and more easily managed.

Fig. 166.

CCCX. By means of attraction and repulsion, a great variety of elegant and amusing experiments may be made

CCCVIII. How is the machine put in order? What is used to increase the effect, and how is it prepared? CCCIX. Which kind of machine is preferable, and why? CCCX. What experiment with head of hair?

with the electrical machine. Among the most striking of these is the head of hair, which stands on end when excited, in consequence of the repulsion of the similarly electrified hairs. A similar experiment is made by placing a person upon the insulating stool, in connexion with the prime conductor of the machine as seen in figure 166.

CCCXI. The electric bells, the pantomime dance, the electric fly-wheel, the electric orrery, luminous words, &c., are all highly interesting and amusing experiments.

CCCXII. The electric bells consist of three or more small bells as seen in fig. 167, suspended from a conductor by brass chains, with balls to act as clappers, suspended by silk threads between the bells—the middle one of which communicates with the table by means of a chain to carry off the excess of the electric fluid as fast as received. Thus the insulated ball will vibrate backward and forward to the electrified and to the non-electrified bell, as soon as the machine is put in motion.

Fig. 167.

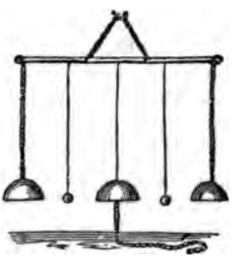
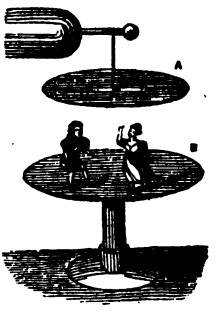


Fig. 168.



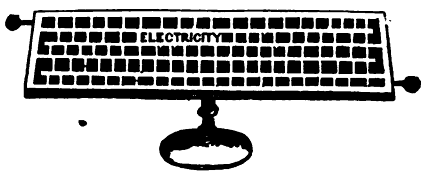
CCCXIII. The pantomime dance is generally performed by preparing images of men and women in pith or paper, and placing them on a brass plate B, connected with the ground, and having another plate A, a little above it suspended from the prime conductor, as seen in fig. 168; on

CCCXII. Describe the electric bells. CCCXIII. Describe the dancing figures.

turning the electrical machine, the figures will move rapidly from the one to the other plate.

CCCXIV. The "*Luminous Letters*" are nothing more than pieces of tin-foil cut out in the form of letters, and pasted on a pane of glass, so that the letters will be very near each other, but not in contact; and on connecting one extreme of the word or words with the prime conductor, and the other with the hand or some some good conductor, a spark drawn from the conductor, and passing over the letters, will render them luminous, as represented in the wood-cut below.

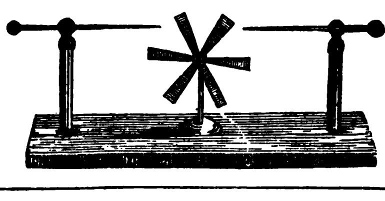
Fig. 169.



CCCXV. A light float-wheel, the vanes of which are made of card paper, turning freely on a pin passed through its centre as an axle, will be put in motion by presenting to it an electrified point, apparently in consequence of the impulse of the stream of air which issues from the point.

Illustration. Whether the point be positively or negatively electrified, the direction of the motion, as well as of the stream of air, is always the same. But if the wheel be placed on an insulating stem, as in the figure below, and introduced between the pointed wires of the universal discharger, which are to be placed as accurately as possible opposite to each other, and at the distance of an inch or more from the upper vanes; on connecting one of the wires

Fig. 170.



CCCXIV. Describe the luminous letters. CCCXV. Describe the float-wheel.

with the positive, and the other with the negative conductor of an electrical machine and exciting it, the wheel will move as if impelled by a stream from the positive to the negative wire. On reversing the connexions, so that the electricity of each wire is changed, the motion of the wheel will likewise be reversed.

CCCXVI. The Leyden jar, from its extensive uses in electrical experiments, and the amusement and instruction it affords, merits a particular description. The application and uses of this instrument, like many other valuable discoveries, were the result of accident.

Observation. During the middle part of the 18th century, while the subject of electricity was acquiring considerable notice in Europe, an association of scientific gentlemen at Leyden were amusing themselves with electrical experiments, during which, it occurred to one of them to charge a tumbler of water with electricity, and learn by experiment whether it would affect the taste. Having directed a current of electric fluid for some time into the water, he grasped the tumbler and brought it to his lips, but before he could taste the water, he received the full charge of electricity in the extremity of his nose, which happened to be very prominent. Consternation seized the whole company, and various exaggerated reports were spread throughout the country, of the wonderful discovery and tremendous effects of the electric shock. Jars of water were at first used, but it was at length, proposed to use some substance that was a better conductor; and the jars were partly filled with metallic filings. Subsequently, however, tinfoil was substituted for the metal filings, and this arrangement is now in general use.

Fig. 171.

CCCXVII. The Leyden jar is generally made by coating externally and internally, a wide-mouthed glass jar, with a wire passing through its cap and extending to the bottom. The top of the wire is surmounted by the brass ball A, as seen in the wood-cut.

CCCXVIII. To charge the jar, nothing more is necessary than to present the brass ball A to the prime conductor of the electrical machine, while the latter is in action. The outside of the jar is generally either in connexion with the earth, by means of a chain or with the rubber.

In order to discharge the jar, we use a discharger as represented by B in the wood-cut. The discharge is

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CCCXVI. How was the Leyden jar discovered? What kind of jars were first in use? What was at length substituted? CCCXVII. How are the Leyden jars generally made? CCCXVIII. How is it charged, and how discharged? What remark is made with regard to connecting the outer coating with the earth?

made by presenting one of the knobs *a* to the outside coating, and the other to the brass ball A, as in the position represented in fig. 171.

Observation. It is generally stated in the books, that in order to charge the jar successfully, the outer coating should communicate by means of a chain, or some metallic conductor, with the earth; but it is much better to have the outer coating by means of a chain, in connexion with the rubber; by which means, the outer surface will become highly negative, while the inner one becomes highly positive.

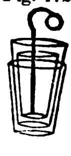
CCCXIX. If, when we have charged the jar, we hold the exterior coating in one hand, and touch the knob with the other, the spark passes as before, and we perceive a peculiar, and in some cases, painful sensation at the wrist and elbows and across the breast, called the *electric shock.* Any number of persons can receive the shock at the same time, by forming themselves in a circle communicating with each other, and letting the first touch the outer coating of the jar, and while his hand rests in contact, let the last one bring his finger to touch the knob, every person in the connexion will feel the shock at the same instant.

Observation. The shock has been made to traverse a distance of four miles, without perceptible lapse of time; hence the motion of the electric fluid must be incalculably rapid.

CCCXX. It is natural to suppose, since we are compelled to coat the jar in order to charge it successfully, that the electricity resides in the coating; but it can be proved to reside in the glass only, for the coatings may be rendered moveable, and thus we can analyze the jar.

Experiment. To a common quart tumbler, of the shape represented in the figure, fit an inside and outside coating of common tin plate, so that the glass shall project considerably above the coatings. To the bottom of the inner coating solder a piece of metallic wire, having a knob on the other end, and let the wire be bent into the form of a hook, for convenience in removing it. Having charged the jar in the usual way, remove the inner coating by means of a glass rod, and set it upon a table; now remove the tumbler by means of the thumb and finger, touching it only on the edge, and while you hold the glass in one hand suspended, the coatings may be brought in contact and handled when they indicate no signs of electricity; return the coatings in their place, and the jar may then be discharged in the ordinary way;

Fig. 172.



CCCXIX. What is said of the electric shock, and the number that can receive it at the same time, and how is it accomplished? Through what space has it been passed, and what is said of it? CCCXX. Where does the electricity reside in the Leyden jar. How proved?

thus proving that the charge resides in the glass, and not in the coatings. The principal use of the coatings is to act as conductors in spreading the electricity over the surface.

LIGHTNING AND ITS PHENOMENA

CCCXXI. It was before stated that lightning was the most fruitful source of electricity, and though it had long been suspected that electric sparks produced by the common electrical machine, were the same as the flashes of lightning so often witnessed in the thunder-storm; yet, until the celebrated experiment of Dr. Franklin, in 1752, no one had been able to prove it.

Observation. Dr. Franklin, a few years previous, in correspondence with Mr. Collinson of London, proposed to erect a spire of metal forty or fifty feet in height, and let it come within about two feet of the ground, being supported by some imperfect conductor, and to watch this spire during a thunder-storm, supposing that if the lightning were identical with common electricity, it would be conducted down the spire, and pass in sparks to the ground; but in June, 1752, while waiting for the erection of a spire in the city of Philadelphia, the sight of a boy's kite, which had been raised for amusement, immediately suggested to him a more expeditious method of obtaining his object.

Having constructed a kite, by stretching a silk handkerchief over two sticks in the form of a cross, on the approach of the first thunder-storm, he went into the field accompanied by his son, to whom alone, for fear of ridicule, he had imparted his design. Having raised his kite, and attached a common door-key to the lower end of the hempen string, he insulated it by lengthening it out with a short piece of silken cord, which was a non-conductor, and this was tied to a post. Under these circumstances, he waited with intense anxiety for the result. Some time had now elapsed, and no signs of electricity appearing, though one or two clouds had passed in the vicinity of the kite; he was just beginning to despair of success, when his attention was caught by the bristling up of the loose fibres of the string; he applied his knuckle to the key, and was rewarded for his labour and ingenuity by the first electric spark that had ever been drawn from the clouds to prove the identity of lightning and electricity. Overcome with the emotion inspired by this decisive evidence of the great discovery he had achieved, we are told that "he heaved a deep sigh, and would have been content if that moment had been his last," for he was confident that his name would be immortalized by the discovery. The rain now fell in torrents, and wetting the string, rendered it a good conductor, so that electric sparks were drawn in abundance, with which the Leyden jar was charged, and all the most common electrical experiments performed. It should be noticed, however, that about a month previous to the experiments of Franklin, Dalibard and Delors, two French philosophers, had obtained similar results by the erection of spires, agreeably with Franklin's recommendations; but the honour

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CCCXXI. What is said of lightning and electricity? What did Franklin propose? What led him to make the experiment with a kite? How was the experiment with the kite made, and what were the circumstances? What is said of Dalibard and Delors?

of the discovery is universally given to Franklin, as it was from his suggestions and recommendations that they, were enabled to accomplish their purpose.

CCCXXII. Lightning is the result of the accumulation of large quantities of electricity in the atmosphere; sometimes one cloud is in the positive state, while another approaching it is in the negative state, and when they have approached sufficiently near, the spark will pass from the positive to the negative cloud, producing the flash of *lightning*. In the space occupied by the flash, the air is suddenly and forcibly separated, and when it comes together again, produces a report which we call *thunder*.

CCCXXIII. Sometimes the cloud in a positive state, instead of approaching a negative cloud, approaches the earth, which happens to be negative, and then the flash passes from the cloud to the earth: in this case, some object is always struck, which is generally the highest object and best conductor; hence high buildings, such as steeples of churches, tall trees, masts of vessels, &c., are generally the objects injured or destroyed by lightning.

CCCXXIV. Notwithstanding the facility and danger of making these experiments, yet only a single case of death is recorded in repeating them, and that was the late Professor Richman, of St. Petersburgh, who approached too near the lower part of an insulated spire during a thunder-storm.

Observation. He was examining the electrometer, which was standing near the lower extremity of the rod, when stooping a little to look more closely at the phenomena, a large globe of electric fire flashed from the conducting rod to his head and passed through his body, destroying him instantly. A red spot was produced upon his forehead, his shoe was burst open, and a part of his vest singed; his companion was for some time rendered senseless; the door of the room was split and torn off its hinges.

CCCXXV. The most important, and therefore most interesting application of the theory of electricity, is in the use of *lightning-rods* to protect buildings, ships, &c. The lightning-rod is generally a thick rod of metal, ar

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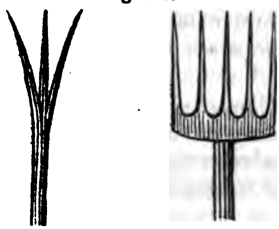
CCCXXII. What is lightning? What is thunder? CCCXXIII. What causes the lightning to strike? CCCXXIV. What is said of Professor Richman? CCCXXV. What are lightning-rods?

ranged perpendicularly beside the building, which it is intended to protect; it should be pointed at each extremity, because points receive and impart the electric fluid silently. The upper end should project above the highest part of the building, the other should penetrate deep in the earth, or in contact with water. Iron is generally used because it is cheaper, but copper is better, because it does not so easily rust. The part that projects above the building, generally terminates in a number of points, thus :—

Fig. 173.



and these are generally of silver, gold or platinum, because those metals do not rust. The rod should be half an inch in diameter.

CCCXXVI. People are often led to inquire what are the best means of safety during a thunder-storm? If out of doors we should avoid trees and elevated objects of every kind; and if the flash is instantly followed by the report, which indicates that the cloud is very near, a recumbent posture is considered the safest. We should avoid rivers, ponds, and all streams of water, because water is a good conductor, and a person on the water, as in a boat, would be the most prominent object, and therefore most likely to be attracted by the lightning.

CCCXXVII. If we are within doors, the middle of a large carpeted room is tolerably safe; we should avoid the chimney, for the iron of and about the grate, the soot

How are they constructed? What metal is generally used? What is the best, and why? What is used for the points? CCCXXVI. Where is the safest place while out of doors in a thunder-storm? CCCXXVII. Where is the safest place in the house? What places should be avoided?

that often lines it, the heated and rarefied air that it contains, are all tolerable conductors, and should on that account be avoided, lest they should be attracted by the lightning.

CCCXXVIII. It is never safe to sit near an open window, because a draught of moist air is a good conductor, and should therefore be avoided; hence we should close the windows on such occasions, as well for avoiding the lightning as the rain. In bed, we are comparatively safe, for the feathers and blankets are bad conductors, and we are, to a certain extent, *insulated* in such situations. All these precautions are generally considered unnecessary in buildings well defended by lightning-rods.

CCCXXIX. There is a variety of amusing experiments for illustrating the effects of lightning upon buildings, by causing electricity to pass through the model of a house, a powder magazine, &c., exhibiting in miniature, the effect of lightning upon buildings.

CCCXXX. There was, at one time, much discussion amongst electricians respecting the relative advantage of balls and points in constructing lightning-rods; but agreeably to Dr. Franklin's original recommendation, points are now universally adopted, because they conduct away the electricity silently. To prove the correctness of this opinion, Dr. Franklin proposed the following experiment:—

Experiment. Attach one or more large flocks of cotton to the prime conductor, so as to resemble electrified clouds; when a point is made to approach them they collapse, recede, and quickly lose their electricity; when, on the other hand, they are approached by a ball, they are attracted towards it, and the electric charge is very slowly dissipated.

CCCXXXI. The *aurora borealis* and *aurora australis*, or the northern and southern lights, are supposed to be caused by currents of electricity passing through the higher regions of the atmosphere to or from the earth, in

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CCCXXVIII. What is said of sitting near a window? CCCXXIX. What experiments referred to with houses, powder magazines, &c. CCCXXX. Why are points preferable to balls in constructing lightning-rods? What experiment was proposed by Franklin? CCCXXXI. What is said of the aurora borealis and the aurora australis?

which case it must pass through such strata as are highly rarefied.

Observation. This opinion is strengthened by the fact that the electric fluid will pass through an exhausted glass vessel, exhibiting much the same appearance as the light of the north. Shooting or falling stars are also considered to be electrical phenomena.

GALVANIC ELECTRICITY—GALVANISM.

CCCXXXII. The term galvanism is used to denote the electricity produced by the corroding action of various materials on plates of different metals, such as that of oil of vitriol upon iron or zinc.

CCCXXXIII. The common experiment of putting a piece of zinc on the surface of the tongue, and a piece of silver under it, and letting the edges come in contact over the tip of the tongue, was described by Sulzer, a German, in 1767, and was the first notice of any fact that comes under the denomination of galvanism. In this experiment, the moment the metals come in contact, a peculiar taste is perceived, and if the eyes be closed, a flash of light at the same instant.

CCCXXXIV. No other fact of this kind was made known until the novel and wonderful experiments of Galvani, the professor of anatomy in the university of Bologna, in Italy, from whose name the term galvanism is derived.

Observation. The discovery was entirely accidental, as the following circumstances show. It happened in the latter part of 1789, that Madame Galvani, then an invalid, was advised by her physician to take, as a nutricious article of diet, soup made of the flesh of frogs. Some of these animals, recently skinned for that purpose, were lying upon a table in the professor's lecture-room, near which a pupil was amusing himself by experiments with the electrical machine. While the machine was in operation, he happened to touch the leg of one of these animals with the blade of a knife which he held in his hand; the whole limb was convulsed at every spark taken from the machine. Galvani, it appears, was not present when this happened, but received a faithful account of it from his lady, who had witnessed with much

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CCCXXXII. Explain the term galvanism. CCCXXXIII. Describe the experiment with silver and zinc. CCCXXXIV. What led to the discoveries in the science of galvanism? Give the history of the discovery.

interest, the whole occurrence. Galvani lost no time in repeating the experiments, and in examining minutely into all the circumstances connected with them.

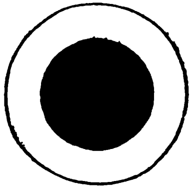
CCCXXXV. The nerves and muscles of animals are most easily affected by the galvanic influence.

Experiment 1. Place a living frog or a flounder upon a plate of zinc, and a piece of copper upon the upper surface of the animal, and connect the two by a piece of copper wire; every time the connexion is made the animal is convulsed by the shock.

2. Let a person go into a dark room, put a piece of silver upon his tongue, and press a piece of tin-foil against the globe of the eye; by making a communication between the two by a small piece of copper wire, at every contact a flash of light will be perceived in the eye.

3. Cut out a large disk of zinc, and a smaller one of copper, thus

Fig. 174.



Moisten the surfaces of the metals, having polished or scoured them so as to produce a clean metal surface, and place the smaller one upon the larger, and upon the former put a common leech, the galvanic shock produced whenever the animal attempts to escape over the zinc, will be so great as to baffle all his efforts.

CCCXXXVI. By repeating and varying the experiments, Galvani soon found that any two metals would answer for his experiments, but that it was necessary to have one easily corroded, while the other was corroded with difficulty, and such were silver and zinc, but as silver was expensive, copper was at length used in its place.

CCCXXXVII. Galvani considered the nerves and muscles of animals in opposite states of electricity, and that the metals merely served as conductors to convey the electricity from the one to the other. *

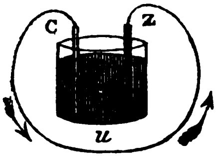
CCCXXXVIII. His experiments were confined to the

CCCXXXV. What is said of galvanic influence on nerves and muscles? Describe the experiment with a frog. Describe that with the silver and tin foil. Describe the experiment with the leech. CCCXXXVI. What was the result of varying the experiment? CCCXXXVII. What was Galvani's theory? CCCXXXVIII. What was the extent of his experiments?

action of the galvanic influence on the animal system, such as the production of shocks, &c. The instrument used was a single pair of plates, and those of small size, consequently the effects produced were small, compared with later results.

CCCXXXIX. The most simple galvanic instrument is formed by placing a plate of zinc near another of copper, in a vessel of water containing a little oil of vitriol, and soldering to each a piece of copper or other metallic wire, the opposite ends of which may be brought together at the will of the experimenter as seen in the wood-cut, in which *z* represents the zinc, and *c* the copper plate.

Fig. 175.



CCCXL. These three substances, namely, the copper, the zinc, and the acid liquor, form what is called a *simple* galvanic *circle*, and the wires which lead off from each of the plates are called the *poles* of the battery—one being *positive*, the other *negative*.

CCCXLI. If, while the ends of the wires which form the poles are unconnected, their electrical state be examined, that connected with the *copper* plate will be *positive*, and that connected with the *zinc*, *negative*.

Observation 1. This illustration is directly the reverse of those given in many of the books where we are taught to say the zinc is the positive and the copper the negative pole of the battery. The true explanation is, the acid about the zinc plate acts upon it and corrodes it, generating a quantity of electricity, and tending to render the zinc positive, but as soon as any electric fluid is excited, it is carried off by the acid in contact, to the copper plate, where it would accumulate were it not for the fact that the wire from the copper plate is a good conductor, and the excess of electricity in the copper plate *c* will be constantly transmitted along the wires in the direction of the arrows to *z*: hence, in all simple galvanic circles, the pole connected with the copper plate is positive, while that connected with the zinc is negative.

2. If a single disk of zinc, having a glass handle for the purpose of insulating it, be brought in contact with another of copper, also insulated, on

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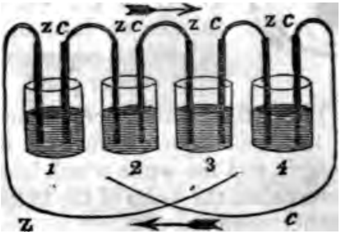
CCCXXXIX. How is a simple galvanic instrument constructed? CCCXL. Describe a simple galvanic circle and the poles. CCCXLI. Which is positive and which negative? How does this illustration correspond with those generally given? Give the true explanation of the phenomena. Describe the experiment with the insulated disk of zinc and copper.

separating them, the zinc will be found in a positive, and the copper in a negative state; hence, there is always a tendency in the zinc to become positive, and in the copper to be negative.

CCCXLII. A single galvanic circle, such as that above described, would not be sufficiently powerful to produce any remarkable effects; but it may be increased to any extent, by increasing the number of pairs of plates, and forming what is called a *compound circle*

Illustration. Thus having arranged many simple circles, such as that described in *Prop.* cccxxxix., if the copper of the first pair or circle be soldered to the zinc of the second by means of a metallic connexion, and the copper of the second to the zinc of the third, and so on as seen in the accompanying figure, the accumulated electricity in the zinc of the first cup

Fig. 176.



is transmitted through the liquid to the copper of the first cup, and by means of the metallic strap to the zinc of the second; and in the same manner, the copper of the second transmits all the electricity of its own pair, as well as all that it received from the first, to the zinc of the third pair; and thus the whole of the electricity, generated by a large battery, is accumnlated at the copper or positive end of the battery, moving in the direction of the arrows, as seen in the figure.

CCCXLIII. The first instrument, formed by uniting many simple circles, was invented by Alexander Volta, professor of natural philosophy at the university at Pavia, in Italy, and denominated the Couronne de Tasses. He was the pupil of Galvani, and was among the first to repeat his experiments.

CCCXLIV. The first instrument invented by Volta, and by which he proved the identity of common and gal

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CCCXLII. How is the compound galvanic circle formed? Describe the illustration by the figure. CCCXLIII. What is said of Volta? CCCXLIV. What is said of the pile?

vanic electricity, was denominated the *pile*, and in honour of the discoverer, the *Voltaic pile.*

Fig. 177.

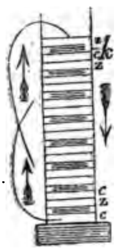
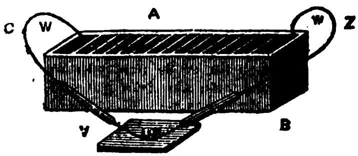


Illustration 1. This instrument is formed by placing pairs of zinc and copper disks one above the other, each pair being separated from those adjoining by disks of cloth, moistened with a solution of common salt, as represented in the wood-cut. Commencing at the top, the electric fluid generated in the zinc plate, is carried through the moistened cloth *k* to the copper, and so on until it has accumulated at the lower or copper extremity of the battery, which is therefore positive, while the opposite end is negative. The Voltaic pile is now seldom used except for exhibiting its construction, because we have more convenient and more powerful batteries, but it will give shocks and produce other remarkable effects such as the decomposition of water, &c.

Fig. 178.



2. The *trough battery* is one of the most convenient and most generally used, and consists of a trough, A B, of dry wood, with grooves cut in the sides and bottom, and into each of these grooves is fitted by cementing, a copper and zinc plate, which have been previously soldered together at their edges; the zinc surfaces facing towards z, and the copper towards c. The cells formed by the plates are made water tight by the cement, and when used, are filled with some liquid that will corrode the plates, such as oil of vitriol and water, or common salt and water; the pole or wire proceeding from c, or the copper end of the battery, will be positive, while that from z will be negative, agreeable to the illustration (*Prop.* cccxli.) If one hand be placed in the first, and the other in the last cell of the battery, a powerful shock will be felt, and will be renewed as often as the communication is repeated. Any number of persons forming a part of the circuit will receive the shock at the same moment.

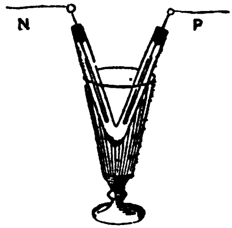
CCCXLV. The most striking phenomena of the galvanic electricity are exhibited in the decomposition of various compounds, and in deflagrating or burning of the metals and charcoal.

CCCXLVI. The first instance of decomposition by

Describe the Voltaic pile. Describe the trough battery. How can a person or persons receive the shock? CCCXLV. What are the most striking phenomena? CCCXLVI What was the first experiment for decomposition?

means of the battery, was that in which water was decomposed by Messrs. Carlisle and Nicholson, on the 30th of April, 1800, in the following manner :—

Fig. 179.



Experiment. A glass tube was bent at an angle, and fitted into a wine-glass as represented in fig. 179; the tubes were filled with water and corked, a small aperture having been made in the bottom part of the tube for the escape of water as fast as the gases accumulate above. The platinum wires P and N are thrust through the corks nearly to the bottom of the tubes; the wires were then connected with the two poles of a battery, P the positive, and N the negative. Oxygen gas was liberated from the positive, and hydrogen from the negative pole, proving thereby that water was composed of these two gases.

CCCXLVII. Various other substances were tried, and it was soon ascertained that nearly all compound bodies could be decomposed by means of the battery; not only known compounds, but many substances, before considered as simple, were ascertained by means of this instrument to be compounds.

Experiment 1. We may substitute for the water used in the last experiment a solution of common salt, containing a little indigo, previously dissolved in oil of vitriol, to give it a deep blue colour. The common salt contains *chlorine* and the alkali *soda;* when in combination, the chlorine produces no sensible effect, but if separated by means of the battery it will instantly bleach the liquid where it is liberated. This is accomplished by connecting the wire P (*Exp. Prop.* cccxlvi.) with the positive pole of the battery in action, and the wire N with the negative pole; chlorine will be set free at the positive pole as indicated by the liquid in that tube suddenly becoming transparent.

2. Making use of the same apparatus, we may still vary the experiment by substituting for the compound last used, water which has dissolved in it a salt called hydriodate of potash, (containing *iodine* and *potash*,) and in it dissolve a little *starch*. Iodine, when in a state of chymical combination,

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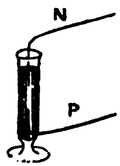
Describe the experiment. CCCXLVII. What is said of other experiments? What was the experiment with solution of common salt and indigo? What experiment was made with the hydriodate of potash?

has no effect on starch, but in a free state it instantly colours it a deep blue. Connecting the wires with the poles of the battery as before, the liquid in the tube next the positive wire will be quickly changed to a deep blue from the liberation of iodine, proving that a chymical change has been produced.

CCCXLVIII. We have seen in the above experiments that when water was decomposed, the oxygen appeared at the positive pole, and that in the two last the chlorine and iodine was separated at the same pole. If any neutral salt (a compound of an acid and an alkali) be decomposed the acid will go to the positive, and the alkali to the negative pole; if it be a metallic salt, that is the combination of an acid with some metallic base, then the acid will go to the positive, and the metal to the negative pole.

Experiment 1. Dissolve some glauber's salt (a compound of oil of vitriol or sulphuric acid and the alkali soda,) in water previously coloured with blue cobbage, and with this fill the abovenamed apparatus, and connect the wire P with the positive pole, and N with the negative, the tube P will soon begin to redden by the liberation of the acid, while N will become green, showing that the alkali is also liberated. If the wires be reversed the colours will also be reversed, N will be green and P red.

Fig. 180.



2. Dissolve some sugar of lead (a salt containing vinegar or acetic acid and lead) in rainwater, and fill the jar represented in the wood-cut with the solution. On connecting the wire P with the positive, and N with the negative pole, crystals of pure lead will appear around that part of the wire N which is immersed in the solution, and the acid will, at the same time, appear around the pole P.

CCCXLIX. It was by exposing the alkalies, potash and soda, and the earths lime, clay, magnesia, &c., to the action of a powerful galvanic battery, that Sir Humphrey Davy was enabled to decompose these bodies, and prove them to be composed of different metals, united to oxygen.

Illustration. For instance, potash is composed of the metal potassium and oxygen; soda, of the metal sodium and oxygen; magnesia, of magnesium and oxygen, &c.

CCCL. From the above experiments is deduced the following law; that in the decomposition of various chymi-

CCCXLVIII. What is the law with regard to the preceding experiments and others referred to? Describe the experiment with glauber's salt. Describe that with sugar of lead. CCCXLIX. What is said of the discovery of Davy? CCCL. What bodies are carried to the positive, and what to the negative pole?

cal compounds, the oxygen and the acids which contain it, the chlorine, iodine, &c., go to the positive pole; while hydrogen, the alkalies, the earths and the metals, go to the negative pole.

CCCLI. If a piece of gold or silver leaf be brought between the poles of a powerful battery when in operation, they are instantly consumed; the former, giving off a splendid white light tinged with blue, and the latter, a brilliant green of the emerald teint, and the light is still more intense than that from gold; copper burns with a bluish white light, throwing off red sparks; lead gives a vivid purple: indeed, the most refractory metals are not only melted, but dissipated in vapour by means of this instrument.

CCCLII. The light given off, when small pieces of charcoal are substituted for the metallic leaves, is equal in brilliancy to that of the sun, and the heat is greater, perhaps, than that from any other artificial source.

CCCLIII. If we wish to perform experiments of decomposition, or to produce shocks, we require a number of plates, and their size may be small; but, if we wish to produce heating effects, such as burning metallic leaf, igniting charcoal, &c., a few large plates answer better than many small ones.

CCCLIV. The liquid used to corrode the plates, in experiments of decomposition, is generally a solution of common salt in water, or salammoniac in water. But for burning or deflagrating the metals, a mixture of one part nitric, two of sulphuric acid, and thirty parts of water, answers best: sometimes oil of vitriol, diluted with forty or fifty times its weight of water, and a weight of nitre equal to that of the vitriol, is substituted on account of cheapness.

Observation 1. There are many well known phenomena explicable on

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CCCLI. Describe the effect on each of the metals mentioned. CCCLII. What is said of the light and heat of the charcoal? CCCLIII. What is requisite to decompose and produce shocks? CCCLIV. What liquids are to be used? What is said of drinking porter?

galvanic principles. Porter has a more lively and agreeable taste from a pewter or silver cup, than from a glass one; in the former case, the moisture of the under lip, the metallic cup and the porter, form a simple galvanic circle, which gives rise to the peculiar taste.

2. *Silver spoons* are blackened in eating boiled eggs—here a galvanic circle is formed by the silver, the sulphur, and the saline or saltish matters contained in the egg; in which case, the sulphur combines with the silver, forming a blackish compound, called *sulphuret of silver*.

3. Iron railing is generally fastened into stone work by means of lead, and the iron always corrodes first, at the juncture of the lead and iron with the stone; in this case, the moisture, together with the two metals, form a galvanic circle, in which the iron is the most oxidizable metal, and is most rapidly corroded.

MAGNETIC ELECTRICITY.

CCCLV. By the term *magnetism*, (from Magnes, the discoverer of this property in the loadstone,) as it has generally been used, is understood that property which the loadstone has in attracting iron and steel, the magnetic needle in pointing to the poles of the earth, &c.

CCCLVI. The power of lightning in reversing and destroying the poles of the magnetic needle, and rendering iron and steel magnetic, has been long known; thus rendering it evident that there is some connexion between electricity and magnetism; but it was not until the discovery of Professor Oersted, of Copenhagen, in 1819, that this connexion could be proved by experiment.

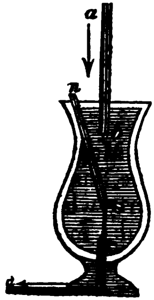
Illustration. In the winter of 1819, Professor Oersted observed, that when the wire which connects the positive and negative pole of the battery in action, is brought near to, and parallel with the magnetic needle, it causes the poles of the needle to deviate from their natural position, and assume a new one, the direction of which depends on the relative position of the needle and wire with regard to each other. Suppose the current of electric fluid to move from the south toward the north pole, this pole will therefore correspond with the negative pole of the battery; and suppose the wire to be placed parallel with, and directly over the needle, its north pole will move westward; placing the wire on the east side, the same pole will be elevated; place the wire under the needle, the pole will then move eastward; place the wire on the west side, and the pole will be depressed. Such was the discovery, and such the experiments of Oerstead.

What is said of the action of eggs on silver? What of iron railing? CCCLV. What is understood by the term magnetism? CCCLVI. What effect of lightning is here mentioned, and what is mentioned of Oersted? What was Oersted's discovery?

CCCLVII. On examining the above experiments, Professor Faraday, of London, concluded that there was a tendency in the poles of the needle to revolve around the wire, and that when the wire was moveable, and the needle fixed, the former would revolve around the latter, both of which he soon succeeded in proving by experiment, in the following manner:—

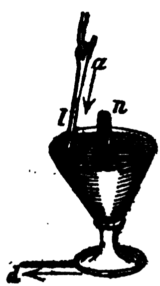
The Magnet revolving about the Conducting Wire.

Fig. 181.



Experiment 1. In the figure 181, the north pole of the magnet *n s* is represented as revolving around the fixed connecting wire *a b*, the other part of the connecting wire, namely, *c d*, is connected to the magnet by the string *s c*, and to complete the metallic connexion, the cup is nearly filled with mercury. The wire *a* is connected with the positive, and the wire *d* with the negative pole of a powerful galvanic battery in a state of excitement, and the north pole *n* of the moveable magnet, immediately commences revolving around the wire *a b*, passing from east through the south to west. If the poles of the battery be reversed, the magnet will revolve in the opposite direction.

Fig. 182.



The Wire revolving about the Magnet.

2. The wire being moveable, and the magnet fixed, the former may be made to revolve around the latter. In the accompanying figure, *n* represents the fixed magnet passing through the bottom of the cup and communicating with the wire *d*, *a b* represents the other portion of the connecting wire as moveable about the magnet. The cup is nearly filled with mercury, so that the wire *a b* dips into it. On connecting the wire *a b* with the positive, and the wire *d* with the negative pole of a battery in action, the wire will revolve around the magnet in the same manner as the magnet in the last experiment revolved around the wire. Hence we infer that there is a mutual tendency in the magnet and the connecting wire to rotate around each other.

CCCLVIII. Ampere, a French philosopher, invented an apparatus of this kind, in which the battery itself is made to revolve around the poles of a magnet.

CCCLVII. What was Faraday's conclusion? Describe the experiment for the revolving magnet. Describe the experiment of the revolving wire. CCCLVIII. What was Ampere's invention?

Figure 183 represents a horseshoe magnet *m* with a revolving bucket upon its pole *n*. Figure 184, a section of the same instrument.

Fig. 183.

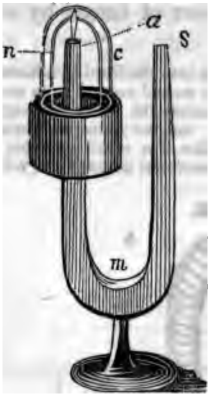


Fig. 184

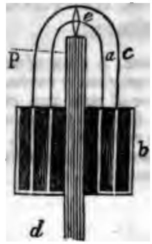


Illustration 1. A cup is made of two copper cylinders, the outer one two inches, and the inner, one inch, in diameter. The smaller one being placed within the other, a bottom is soldered between the two, so as to form a double cup, one within the other, but leaving the inner one without a bottom. The space between the two cylinders, forms a cup containing the diluted acid; a wire bail is formed, and soldered to the opposite sides of the inner cylinder as seen in fig. 184, where *a* represents the bail. From the centre of this bail, a point projects downward, resting upon *p* one of the poles of a strong magnet, upon which it can freely turn. A second tube or cylinder of zinc, one inch and a half in diameter, and open at both ends, is suspended by the bail *c*, (figure 184,) and turns on the pivot *e*. The cylinder of zinc hangs within the copper cup, without touching it. The cups being suspended upon fine points, revolve with but little friction.

Fig. 185.

Experiment. To exhibit an experiment with this apparatus, we remove the cylinder *c*, pour into the cup *b* a little oil of vitriol and water, and replace the zinc, which, on being left free, will immediately begin to revolve around the pole of the magnet. It will revolve on either pole, but the revolution on the north, will be the reverse of that on the south pole.

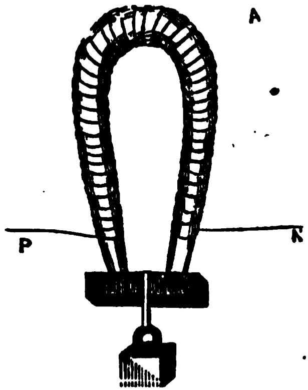
Illustration 2. All the above revolving movements are explained, by supposing that a current of the electric fluid, is constantly passing both around, and through the substance of the magnet, moving in the direction represented by the arrows in the wood-cut; and that this current has a tendency to carry all bodies along with it, and the result is a rotary motion.

Describe the experiment with the apparatus here illustrated. What is the theory of the abovementioned movements?

CCCLIX. A powerful magnet may be made in an instant of a piece of soft iron, by transmitting over its surface, a current of electricity; this property is soon lost, but may be recovered any number of times, by repeating the experiment.

Experiment. A piece of soft iron is bent into the form of a horseshoe, and copper wire previously covered with silk is wound around it, as seen in figure 186. A piece of soft iron called an armature, to which a weight may be attached, is fitted to the two ends of the magnet; and on connecting the ends of the wires N and P, with the poles of a small galvanic battery in action, the soft iron instantly becomes a powerful magnet and will support a great weight.

Fig. 186.



Observation. The most powerful instrument of this kind ever invented, was constructed about three years ago, by Prof. Henry, of Princeton College, in New Jersey. The magnet weighed about 100 lbs., and supported 2,500 lbs., and was supposed to be able to support 4,000 lbs.

CCCLX. The latest and perhaps most important discovery that has been made in this branch of science, was achieved by Professor Faraday, namely, the production of an electric spark by means of a temporary magnet; others have since succeeded, with a common artificial magnet, not

CCCLIX. How may a powerful temporary magnet be made? Illustrate the experiment. What is the strength of the most powerful magnet ever constructed? What was its weight? what would it support, and by whom was it made? CCCLX. What is the latest and most important discovery, and by whom achieved? What other effects have been produced, and what inference is drawn?

only in producing the electric spark, but in decomposing water, giving the shock, and producing all the most important electrical experiments; hence, it is inferred, that electrical and magnetic phenomena, are the result of one common cause; or that electricity and magnetism, are but modifications of the same principle.

ASTRONOMY.

I. ASTRONOMY is the science which explains the nature, motions, and appearances of the heavenly bodies.

II. The heavenly bodies are divided into planets, fixed stars, and comets.

III. The planets are those heavenly bodies that move in circular paths around the sun as, the Earth, Jupiter, Saturn and Herschel.

IV. The planets are frequently attended by smaller bodies, called satellites or moons, which revolve around them.

Observation. Thus the earth has one moon; Jupiter, four; Saturn, seven, and Herschel, six. These planets are frequently called primary, and their moons secondary planets.

V. Fixed stars are so denominated because they do not appear to change their places in the heavens, and are believed to shine by their own light, whereas the planets shine by the light they reflect from the sun.

Observation. The sun is one of the fixed stars, and is so near the earth, that his light is supposed to come to the earth in eight minutes, while that

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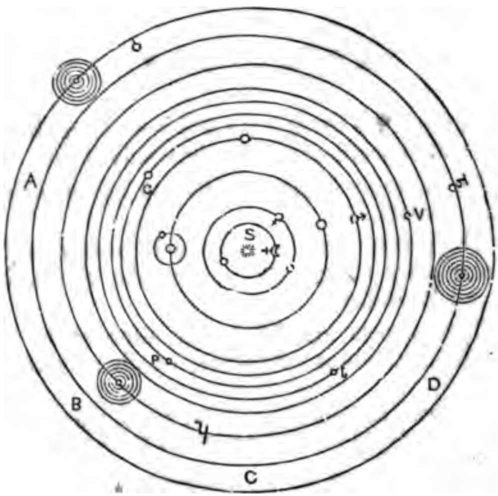
I. Define Astronomy. II. How are the heavenly bodies divided? III. Describe the planets. IV. What are satellites? V. Define fixed stars. Give the observation.

from the dog-star requires three years to reach us; this fact will give some idea of the great distance of the fixed stars.

VI. The comets are irregular bodies which move around the sun in paths or orbits, which are very eccentric, called *ellipses*, and usually accompanied with a long train of light.

VII. The solar system consists of the sun in the centre, and all the planets with their moons revolving around him at different distances, and in different times as represented in the diagram.

Fig. 1.



VIII. There are eleven primary planets, namely:— Mercury ☿, Venus ♀, the Earth ⊕, Mars ♂, Vesta ⚶, Juno ⚵, Ceres ⚳, Pallas ⚴, Jupiter ♃, Saturn ♄, and Uranus or Herschel ♅.

Eighteen secondary planets, or satellites, namely:—

VI. Define comets. VII. Describe the solar system.

the earth's moon, Jupiter's four, Saturn s seven, and Herschel's six.

There is also a considerable but indeterminate number of comets.

DEFINITIONS.

IX. The *orbit* of any celestial body is the curve or path it describes in revolving round another body.

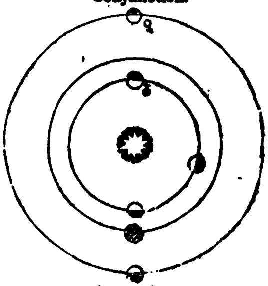
X. Two celestial bodies are said to be in *opposition*, when they are in opposite points of the heavens.

XI. Two celestial bodies are said to be in *conjunction*, when they are in the same point of the heavens.

Illustration. Thus, figure 2, Mars seen by the spectator on the earth in an opposite direction to that where the sun is, is said to be in opposition to the sun, but when seen in the same direction as the sun, at the word *conjunction* it is then said to be in conjunction with the same.

Fig. 2.

Conjunction.



Opposition.

XII. A planet is said to move *direct*, when it appears to move according to the signs of the ecliptic.

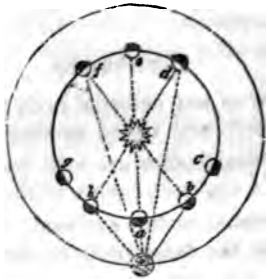
XIII. A planet is said to move *retrograde*, when it appears to move contrary to the signs of the ecliptic.

XIV. A planet is said to be *stationary*, when it appears to remain any particular time in a certain point of the heavens.

Illustration. Thus a planet as *a*, fig. 3, in moving from *d* to *f*, will appear to

move directly, from *g* to *h* it will appear stationary, from *h* to *b* it will appear retrograde, and from *b* to *c* it will again appear stationary.

Fig. 3.



XV. A *circle* is a plane figure bounded by a curved line, called the circumference, every part of which is equally distant from the centre.

XVI. The *diameter* of a circle is a line drawn through the centre, terminated both ways by the circumference.

XVII. The *radius* of a circle is a straight line drawn in either direction, from the centre to the circumference.

XVIII. A *semicircle* is any half of a circle or circumference, cut off from the other half by the diameter.

XIX. A *quadrant* is half a semicircle or circumference; or it is one fourth of a whole circle.

XX. All *circles*, whether great or small, are supposed to be divided into 360 equal parts, called degrees, and are marked °.

XXI. Each *degree* is divided into sixty minutes, marked ′; and each minute is divided into sixty seconds, marked ″.

XXII. An *arc* of a circle is any portion of the circumference, less than one half, or less than a semicircle.

XXIII. The *chord* of a circle is a straight line joining together the extremities of an arc.

XXIV. An *angle* is the space contained between two lines meeting in a point.

XXV. A *right* angle is an angle formed by one line falling perpendicular upon another line, containing ninety degrees, or the quadrant of a circle.

XXVI. An *obtuse* angle is greater than a right angle, containing more than the quadrant of a circle or ninety degrees.

XXVII. An *acute* angle is less than a right angle; containing less than ninety degrees, or the quadrant of a circle.

XXVIII. *Parallel lines*, whether straight or circular, are every where at the same distance from each other; and, if drawn ever so far either way, will never meet.

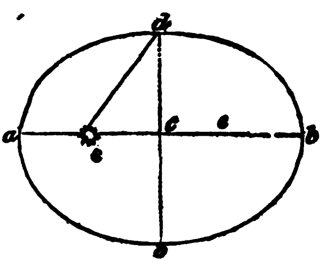
XXIX. A *sphere* is properly a globe; but in astronomy, the celestial sphere means the apparently concave surface of the heavens, in which all the heavenly bodies appear to be placed.

XXX. *Concentric circles* are circles drawn ronnd the same centre, at different distances from it.

XXXI. *Cardinal points* are certain fixed points that never change, and to which all calculations are referred.

XXXII. An *ellipsis* is an oval. This figure differs from a circle, in being unequal in its diameters, and in having two points called its *foci*. See fig. 4.

Fig. 4.



XXXIII. The *foci* are the two points in the longest axis of an ellipsis, on which as centres the figure is described, as *s* and *e*, fig, 4.

XXXIV. The *eccentricity* of an ellipsis is the distance between the centre and either foci, as *s c* or *e c*, fig. 4.

XXXV. When the earth or any other planet is in that part of its orbit nearest the sun, it is said to be in its *perihelion*, as at *a*, fig. 4 ; and when in that part farthest from the sun, as at *b*, it is said to be in its *aphelion*. The line *s d* represents its *mean distance*.

XXXVI. The *axis* of a planet is an imaginary line passing through its centre, terminating at the extremities by the *poles*.

XXXVII. Mercury and Venus are called *inferior* planets because their orbits are within that of the Earth; while those of all the other planets being without that of the Earth, they are called *superior*.

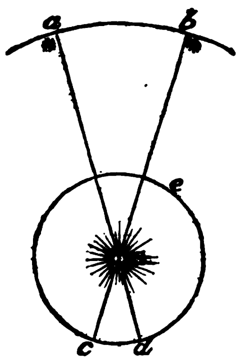
XXXVIII. The Ecliptic is the Sun's apparent annual path through the heavens. Thus the Sun appears to rise in the east, ascend to the zenith, and set in the west; and as the Earth makes one complete revolution around the Sun each year, so the Sun to a spectator on the Earth would appear to make a revolution around the Earth in the same time but in an opposite direction.

Let us suppose a circular table top, the circumference would represent the orbit of a planet, and the whole surface of the table, the plane of its orbit. The apparent motion of the Sun, arising from the real motion of the Earth, will be further explained by the following illustration, and diagram, where the orbit of the Earth, the Sun and a portion of the ecliptic are represented in their respective places, and the apparent motion of the Sun, as arising from the motion of the Earth.

XXXV. Define perihelion, apnelion, and mean distance. XXXVI. Define the axis of a planet. Define the poles, &c. XXXVII. Define the terms superior and inferior. XXXVIII. Define ecliptic.

Illustration. Let $c\ d\ e$ represent the orbit of the Earth, around the Sun s, and the curved line $a\ b$, a portion of the ecliptic: while the Earth is at c, the Sun viewed by a spectator on the Earth will appear to be at b, but as the Earth moves on in its orbit to d, the Sun will appear to move from b to a in an opposite direction.

Fig. 5.



XXXIX. The zodiac is a broad belt or portion of the heavens parallel with the equator and extends 8 degrees on each side of it. It includes the orbits of all the planets except some of the asteroids.

The zodiac is divided into 12 equal parts called the *signs of the zodiac.*

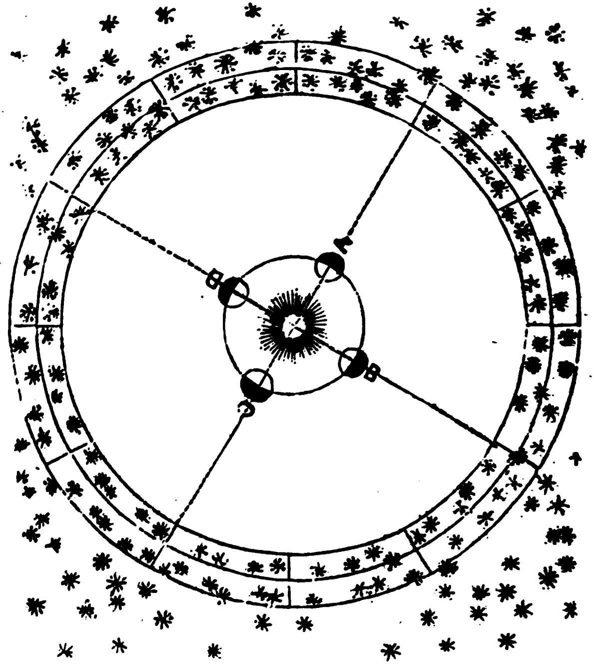
The names of the signs are somewhat fanciful, but refer to the business of the seasons which they represent. Their names are as follows :—

Aries ♈, the Ram; Taurus ♉, the Bull; Gemini ♊, the Twins; Cancer ♋, the Crab; Leo ♌, the Lion; Virgo ♍, the Virgin; Libra ♎, the balance; Scorpio ♏, the Scorpion; Sagittarius ♐, the Archer; Capricornus ♑, the Goat; Aquarius ♒, the Water Bearer; and Pisces ♓, the Fishes. The first six are northern and the latter six are southern signs.

XXXIX. Describe the zodiac, and the origin of the names of the signs.

The diagram below represents the position of the twelve signs arranged in the twelve divisions on the circumference. The circle A, B, C, D, is the orbit of the Earth, and the Sun is seen in the centre. While the Earth remains at A, the Sun will appear to be in the sign *Aries*, at the extremity of the line A C, looking towards C. And when the Earth has passed from A through B, around to C, the Sun will have passed through all the signs from C through D to A; that is, through *Aries*, *Taurus*, *Gemini*, *Cancer*, *Leo*, and *Virgo*.

Fig. 6.



Illustrate by the diagram.

THE SUN.

XL. The Sun is the largest body in the solar system, around which as a common centre, all the planets revolve and from which they receive both light and and caloric.

XLI. The Sun is a little more than 95,000,000 of miles from the earth, and his diameter a little more than 880,000; hence the amount of matter in the Sun, as compared with that of our earth, is *thirteen hundred thousand* times greater.

Observation. The size of this great body may be better appreciated by comparing it with some smaller body, with which we are more familiar. Thus the Moon is forty-nine times less than the Earth, around which it revolves as a centre, at the distance of 240,000 miles, the orbit of the Moon is consequently 480,000 miles in diameter, but the diameter of the Sun is 880,-000, miles; hence, if the Sun were placed where our Earth is, its surface would extend not only to the Moon but 200,000 miles beyond it. At the rate of 90 miles per day, a traveller would circumnavigate the Sun in a little more than 78 years.

XLII. As before stated, the Sun appears to revolve around the earth daily; this appearance arises from the rotation of the earth on its axis.

XLIII. The Sun revolves on his axis in 25 days, 9 hours and 36 minutes, or nearly 25 days and 10 hours; a fact ascertained from dark spots seen on its surface. These spots are first seen on the eastern line or edge of his disk, and progressively extend to the middle, and finally disappear at the western edge, and in 25 days and nearly 10 hours, reappear on the eastern edge of the disk.

XLIV. Spots on the Sun, it is believed, were first noticed by Galileo in 1611, and subsequently by Scheirer, Harriot, Fabricus, Herschel, and others. They are found to vary much in their appearance, sometimes two or more

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XL. What is the Sun? XLI. What is said of its size and distance? XLII. What is the appearance of the Sun? XLII. What is said of the revolution of the Sun on his axis? XLIV. What is said of the spots on the Sun?

small ones unite and become one large one, at others, one large one divides into several small ones; sometimes a single spot continues for many days, and weeks at others; while others appear and disappear in a few hours, and as a general rule, those that rapidly appear, disappear much in the same manner. They have been frequently seen since the 18th century, and occasionally, it is said, with the naked eye, as in the summer of 1815; such spots it is estimated could not be less than 50,000 miles in diameter.

XLV. The nature of these spots is still involved in obscurity—some have supposed them small satellites revolving around the Sun, but the most plausible theory supposes these dark spots are spaces where the luminous clouds do not cover the Sun's surface, and thus a dark space is exhibited.

The nature of the material in the Sun which produces light and heat in the planets, is left equally obscure with that of the spots above described; while one class of philosophers considers the Sun as a vast globe of fire, another considers it as a globe of moderate temperature and capable of sustaining animal life like our Earth. Such philosophers consider the light as arising from luminous or phosphorescent clouds, and the dark spots occasionally visible, arise from the openings in the luminous clouds, through which the true surface of the Sun is seen.

XLVI. The resemblance of the Sun to the other bodies of the solar system, in its supposed material composition, its atmosphere, its diversified surface, revolving upon its axis, &c., has rendered it possible if not probable that the Sun is peopled by animated beings; such was the opinion of Dr. Wilson, and this was strengthened by the observations of the late Dr. Herschel.

XLV. What theories have been formed to explain these spots? XLVI. What is said of the suggestions of Wilson?

Observation. Observations with telescopes, have afforded, it is true, much valuable information, which when applied to bulk or quantity of matter, is both certain and definite; but when applied to heat, the effect of light, or other imponderable agents, our information is only inferential, and in many cases the analogy is so feeble, that little dependance can be put in the results of our reasoning. For example, what do we know of the effect of the rays of the Sun on matter at greater or less distances from him, than that of our Earth? If the heat produced, be in exact proportion to the quantity of light, it has been estimated that the heat on the planet Mercury, must be so great that water would there be converted to steam, and could not exist in the liquid state; and on the surface of Herschel it could exist in no other than the solid state; but these opinions are founded on the effects produced by light, at our distance from the Sun; for except by anlaogy, we know nothing of the effect of the Sun's rays on matter, at a greater or less distance.

MERCURY.

XLVII. Mercury is the planet situated nearest to the Sun, about which it revolves from west to east in about 24 hours, making its day about the same length as ours.

XLVIII. Mercury completes his revolution around the sun in about 88 days, and is about 37,000,000 of miles from the Sun. The year of Mercury is, therefore, equal to about one fourth of our year.

XLIX. Its diameter is 2984 miles—and its size, therefore, about 17 times less than that of the Earth, and twenty millions of times less than the Sun.

Observation. See the figure (1) representing the solar system with the relative positions of the bodies composing it.

L. Mercury from being situated so much nearer the Sun, receives from him seven times the light that the Earth does; and if, as is conjectured by some, the Sun be a mass of igneous matter, Mercury must receive from him the same increased proportion of heat as of light, and hence it has been calculated, that the heat on this planet is sufficient to boil water.

Observation. The hypothesis that the Sun is a mass of fire, it must be

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XLVII. Describe the situation and revolutions of Mercury? XLVIII. Describe its revolution about the sun, its distance, and the length of its year. XLIX. What is its diameter? L. What is said of its light and heat?

recollected, is by no means settled as a matter of fact, but it is to be received as a theory or position that has been assumed by some.

LI. Owing to the dazzling brightness of Mercury and the swiftness of his motions, comparatively few discoveries have been made respecting it.

LII. When viewed through a telescope of considerable magnifying power, it exhibits at different periods all the phases or appearances that the Moon does to us, except that it never appears quite full, but always a little horned.

Observation. The fact that its enlightened surface is always towards the Sun, and the opposite one always dark, proves that it is opaque, and shines only by reflecting light received from the Sun.

LIII. The rotation of Mercury on its axis was proved from the position of its horns, and from spots seen on its surface.

LIV. During a few days in March and April, and in August and September, Mercury may be seen for several minutes in morning or evening twilight, but in all other parts of the year it is too near the Sun to be perceived by the naked eye. Its greatest distance from the Sun either way is 28° 48′.

LV. The revolution of Mercury about the Sun, like that of all the planets, is performed from west to east, in an orbit which is nearly circular. Its *apparent* motion, as seen from the Earth, is alternately, from west to east, and from east to west, nearly in straight lines; sometimes, directly across the face of the Sun, but at all other times, either a little above or a little below it.

LVI. Being commonly immersed in the Sun's rays in the evening, and thus continuing invisible till it emerges from them in the morning, it appeared to the ancients like two distinct stars. A long series of observations was requisite, before they recognised the identity of the star which was seen to recede from the Sun in the morning with that which approached it in the evening. But as the

LI. What is said of the discoveries in Mercury? LII. What are its appearances? LIII. How was its rotation proved? LIV. What is said of the times when Mercury can be seen? LV. What is said of its orbit and apparent motion? LVI. How did it appear to the ancients, and how was it explained?

one was never seen until the other disappeared, both were at last found to be the *same* planet, which thus oscillated on each side of the Sun.

LVII. Mercury's oscillation from west to east, or from east to west, is really accomplished in just half the time of its revolution, which is about 44 days; but as the Earth, in the meantime, follows the Sun in the same direction, the apparent elongations will be prolonged to between 55 and 65 days.

LVIII. When Mercury passes directly over the sun's disk, it is denominated a *Transit*. This would happen in every revolution, if the orbit lay in the same plane with the orbit of the earth. But it does not; it cuts the earth's orbit in two opposite points, as the ecliptic does the equator, but at an angle three times less.

LIX. These points of intersection are called the *nodes* of the orbit. Mercury's ascending node is in the 16th degree of Taurus, its descending node in the 16th degree of Scorpio. As the Earth passes these nodes in November and May, the transits of Mercury must happen for many ages to come, in one of these months.

Observation. The following is a list of all the transits of Mercury from the time the first was observed by Gassendi, November 6, 1631, to the end of the present century.

1631	Nov. 6.	1707	May 5.	1776	Nov. 2.	1835	Nov. 7.
1644	Nov. 6.	1710	Nov. 6.	1782	Nov. 12.	1845	May 8.
1751	Nov. 2	1723	Nov. 9.	1786	May 3.	1848	Nov. 9.
1661	May 3.	1736	Nov. 10.	1789	Nov. 5.	1861	Nov. 11.
1664	Nov. 4.	1740	Nov. 2.	1799	May 7.	1868	Nov. 4.
1674	May 6.	1743	Nov. 4.	1802	Nov. 8.	1878	May 6.
1677	Nov. 7.	1753	May 5.	1815	Nov. 11.	1881	Nov. 7.
1690	Nov. 9.	1756	Nov. 6.	1822	Nov. 4.	1891	May 9.
1697	Nov. 2.	1769	Nov. 9.	1832	May 5.	1894	Nov. 10.

The *sidereal* revolution of a planet respects its *absolute* motion; and is measured by the time the planet takes to revolve from any fixed star to the same star again.

The *synodical* revolution of a planet respects its *relative* motion, and is measured by the time that a planet occupies in coming back to the same position with respect to the Earth and the Sun.

The sidereal revolution of Mercury is 87d., 23h., 15m., 44s. Its *synodical*

LVII. What time required to perform its oscillation, from one side of the Sun to the other? LVIII. What is said of the transits of Mercury? LIX. What is said of the nodes of Mercury? Define the sidereal and synodical revolutions of a planet.

revolution is found by dividing the whole circumference of 360° by its relative motion in respect to the Earth. Thus, the mean daily motion of Mercury is 14732″.555; that of the earth is 3548″.318; and their difference is 11184″.237, being Mercury's relative motion, or what it gains on the Earth every day. Now by simple proportion, 11184″.237 is to 1 day, as 360° is to 115d., 21h., 3m., 25s., the period of a synodical revolution of Mercury.

LX. The absolute motion of Mercury in its orbit is 109,757 miles an hour; that of the Earth is 68,288 miles; the difference, 41,469 miles, is the mean relative motion of this planet, with respect to the Earth

VENUS.

LXI. Venus is the second planet from the Sun, and appears to us the brightest of all the starry bodies, and is hence easily distinguished from the others.

LXII. If we observe this planet for several days, we shall find that it does not remain constantly at the same distance from the Sun, but that it appears to approach or recede from him, at the rate of about three fifths of a degree every day; and that it is sometimes on the east side of him, and sometimes on the west, thus continually oscillating backward and forward between certain limits.

LXIII. As Venus never departs quite 48° from the sun, it is never seen at midnight, nor in opposition to that luminary; being visible only about three hours after sunset, and as long before sunrise, according as its right ascension is greater or less than that of the Sun. At first, we behold it only a few minutes after sunset; the next evening we hardly discover any sensible change in its position; but after a few days, we perceive that it has fallen considerably behind the Sun, and that it continues to depart farther and farther from him, setting later and later every evening, until the distance between it and the Sun, is equal to half the space from the horizon to the zenith, or about 46°.

LXIV. It now begins to return towards the Sun,

LX. What is said of the absolute motion of Mercury? LXIII. Why is it never seen at midnight, nor in opposition to the Sun? At what times is it visible? How long after sunset is it when we first behold it in the west? LXIV. Describe its changes of position.

making the same daily progress that it did in separating from him, and to set earlier and earlier every succeeding evening, until it finally sets with the Sun, and is lost in the splendour of his light.

A few days after the phenomena we have now described, we perceive in the morning, near the eastern horizon, a bright star which was not visible before. This also is Venus, and now called the *morning-star*. It departs farther and farther from the Sun, rising a little earlier every day, until it is seen about 46° west of him, where it appears stationary for a few days; then it resumes its course towards the Sun, appearing later and later every morning until it rises with the Sun, and we cease to behold it. In a few days, the evening-star again appears in the west, very near the setting-sun, and the same phenomena are again exhibited. Such are the visible appearances of Venus.

LXV. Venus revolves about the Sun from west to east in 224⅔ days, at the distance of about 68,000,000 of miles, moving in her orbit at the rate of 80,000 miles an hour. She turns around on her axis once in 23 hours, 21 minutes, and 7 seconds. Thus her day is about 25 minutes shorter than ours, while her year is equal to 7½ of our months, or 32 weeks.

LXVI. The Sun appears twice as large to the inhabitants of Venus as he does to us, and if the heat received be proportioned to the light, it must be exceedingly hot upon her surface. Her orbit is within the orbit of the Earth; for if it were not, she would be seen as often in opposition to the Sun, as in conjunction with him; but she was never seen rising in the east while the Sun was setting in the west. Nor was she ever seen in quadrature or on the meridian, when the Sun was either rising or setting. Mercury

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LXV. In what direction, and in what time, does Venus revolve about the Sun? What is her distance from the Sun? What is the rate per hour of her motion in her orbit? In what time does she revolve on her axis? How are the lengths of her day and year, compared with those of the Earth? LXVI. How much larger does the Sun appear at Venus than he does at the Earth? How much more light and heat does she receive from him, than the Earth? How much farther is Venus from the Sun than Mercury? On which side of the orbit of Mercury must her orbit be?

being about 28° from the Sun, and Venus 46°, the orbi of Venus must be *outside* of the orbit of Mercury.

LXVII. The *true* diameter of Venus is 7621 miles; but her *apparent* diameter and brightness are constantly varying, according to her distance from the Earth. When Venus and the Earth are on the same side of the Sun, her distance from the Earth is only 26,000,000 of miles; when they are on opposite sides of the Sun, her distance is 164,000,000 of miles. Were the whole of her enlightened hemispheres turned towards us, when she is nearest, she would exhibit a light and brilliancy twenty-five times greater than she generally does, and appear like a small brilliant moon; but at that time, her dark hemisphere is turned towards the Earth.

Illustration. When Venus approaches nearest to the Earth, her *apparent* or observed diameter, is 61″.2; when most remote, it is only 9″.6; now 61″.2÷9″.6 = 41 *nearly;* so that she would appear in the latter case, if then visible, 41 times larger than in the former.

LXVIII. When Venus's right ascension is less than that of the Sun, she rises before him; when greater, she appears after his setting. She continues alternately morning and evening star, for a period of 292 days each time.

LXIX. To those who are but little acquainted with astronomy, it will seem strange, at first, that Venus should apparently continue longer on the east or west side of the Sun, than the whole time of her periodical revolution around him. But it will be easily understood, when it is considered, that while Venus moves around the Sun at the rate of 80,000 miles an hour, the Earth, in the mean-

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LXVII. What is her true diameter? In what proportion do her apparent diameter and brightness constantly vary? What is her distance from the Earth when they are both on the same side of the Sun? What is it when they are on opposite sides of the Sun? Which hemisphere is turned towards the Earth when she is nearest to us? Were her enlightened hemisphere turned towards us at that time, how would her light and brilliancy be, compared with that she generally exhibits, and what would be her appearance? What is the length of her apparent diameter when she is nearest to the Earth? What is it when she is most remote? How much larger would she appear, if visible, in the former case than in the latter? LXVIII. In what circumstances does Venus rise before, and in what set after, the Sun? LXIX. How long does she continue each time, alternately morning and evening star? Why does she appear longer on the east or west side of the Sun, than the whole time of her periodical revolution around him?

time, follows at the rate of 68,000 miles an hour, so that Venus actually gains on the Earth only 12,000 miles an hour, or about $\frac{2}{5}^{\circ}$ in a day. Now it is evident that both planets will appear to keep on the same side of the Sun, until Venus has gained half her orbit, or 180° in advance of the Earth; and this, at a mean rate, will require 292 days.

Illustration. This may be further illustrated thus: Suppose two steamboats, which we will call the *Earth* and *Venus*, set out from the same point, and sail the same way around Long Island, whose circumference is estimated at 300 miles; suppose also, that Venus sails 10 miles an hour, and the Earth 8 miles. Now it is obvious that Venus would be 30 hours in sailing quite around the island, while the Earth, in the same time, would have sailed 240 miles; being, at the end of the first circuit, only 60 miles behind Venus. At the end of Venus's second circuit, the Earth will be 120 miles behind, but yet on the same side of the island. But after Venus shall have performed two complete circuits and one half of another, she will then be 150 miles in advance of the Earth, or just half around the island, and on the opposite side. So it is in respect to the planets.

LXX. Mercury and Venus are called *inferior* planets, because their orbits are *within* the Earth's orbit, or between it and the Sun. The other planets are denominated *superior*, because their orbits are without or beyond the orbit of the Earth. As the orbits of Mercury and Venus lie *within* the Earth's orbit, it is plain, that once in every synodical revolution, each of these planets will be in conjunction or on the same side of the Sun. In the former case, the planet is said to be in its *inferior*, and in the latter case, in its *superior conjunction.*

Illustration. For the illustration of this subject, see the figure illustrating the definitions of conjunction and opposition.

LXXI. Venus passes from her inferior to her superior conjunction in about 292 days. At her inferior conjunction she is 26,000,000 of miles from the Earth; at her superior conjunction, 164,000,000 of miles.

LXXII. It might be supposed that her brilliancy would

Give an illustration of this point. LXX. Why are Mercury and Venus called inferior planets? Why are the other planets termed superior planets? How often, in every synodical revolution, will each of these planets be in conjunction on the same side of the Sun that the Earth is? How often on the opposite side? LXXI. What is said of Venus's distance from the Earth at her superior and inferior conjunction. LXXII. How long is Venus passing from her inferior to her superior conjunction, and what her distance from the Earth in each case?

be increased in the one case, and diminished in the other, this however, is prevented by her enlightened hemisphere being turned more from us as she approaches the Earth, and towards us as she recedes from it; hence her splendour is preserved quite uniform.

LXXIII. Both Venus and Mercury present at different times the different appearances of the Moon, that is sometimes horned, and sometimes nearly full; this fact is an evidence that they revolve around the Sun, and besides, that they are situated between the Earth and Sun.

Observation. It must be remembered, however, that when Venus is quite full, she cannot be seen by the inhabitants of the Earth, except at the times of her transits, which as before stated, only happen once or twice in a century, when she passes directly over the Sun's disk. At every other conjunction, she is either behind the Sun, or so near as to be obscured by the dazzling effect of his light. The opposite diagram, fig. 7, will better illustrate the various appearances of Venus as she moves around the Sun. Here the Earth may be supposed to be below the figure; its orbit being without that of Venus.

LXXIV. From her inferior to her superior conjunction, Venus appears on the west side of the Sun, and hence as the Sun and Venus appear to move from east to west, Venus would be seen some two or three hours before the Sun, and hence, is called the morning star; but from her superior to her inferior conjunction she appears on the east side of the Sun, and consequently appears to follow him when she becomes the evening star.

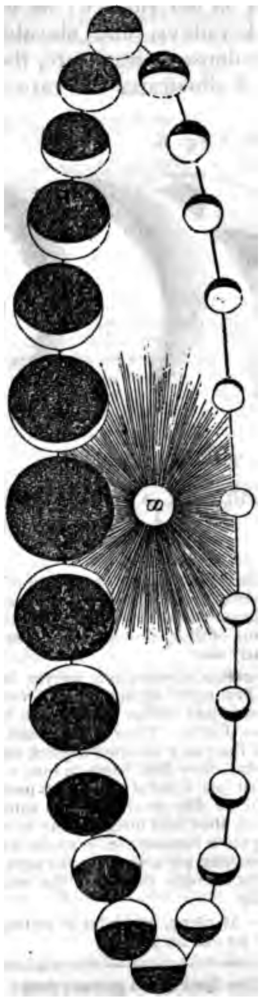
LXXV. The transits of Venus for ages to come, will happen in December or in June; the first ever observed took place, December 4, 1639; the next from the present time, will occur in 1874, and there will be another in 1882.

Observation. The transits of Venus and of Mercury are among the most important astronomical phenomena, and are consequently viewed by astronomers with the most intense interest, for by them are ascertained the relative sizes and distances of the planets from each other, and from the Sun.

LXXVI. Venus when viewed through a good tele-

LXXIII. What is said of the appearances of Venus and Mercury? Give the observation. LXXIV. How does Venus become the morning and evening star? LXXV. What is the history of transits? What their value? LXXVI. Define the telescopic appearances of Venus.

Inferior Conjunction.



Superior Conjunction.

Fig. 7.

APPEARANCES OF VENUS AS SHE MOVES AROUND THE SUN.

scope, exhibits besides the appearances of the Moon, a variety of inequalities on her surface; as dark and brilliant spots, hills and valleys, and elevated mountains. But on account of her dense atmosphere, they are seldom distinctly seen. Fig. 8 illustrates the varied appearances of Venus.

Fig. 8.

THE EARTH.

LXXVII. The Earth is of a globular form, or nearly such, which may be inferred from various considerations.

Observation 1. The most decisive argument in favour of the rotundity of the Earth, is that which is derived from the well-known fact that the Earth has been sailed round at different times by different navigators; and this, combined with the observations of those navigators, is a sufficient proof that the Earth is spherical, or nearly so.

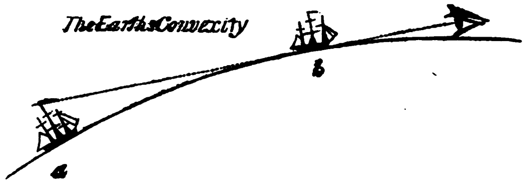
2. A variety of easy but constant observations proves beyond the possibility of doubt, that what, at first sight, appears to be a vast flat or plain, is, in truth, a convex surface; and upon farther inquiry, the convexity is found to be extended quite round the Earth. Thus, it is constantly observed by all mariners, that as they sail from any elevated objects, such as mountains, rocks, steeples of churches, &c., they first begin to lose sight of the lower parts of those objects, and then lose sight of the higher parts, gradually from bottom to top, until they entirely disappear. In the same manner, when navigators approach a country, they first discover the most elevated parts of that country, and the lower parts become visible as the land is approached; or the highest parts of the country are seen from the tops of the mast, and then gradually the lower parts become visible, or the same parts become visible from the deck of the ship.

The Sun is observed sooner at rising, and later at setting, by a person at the mast head of a ship, than by one on deck.

LXXVII. How is it proved that the Earth is of a globular form?

Also, when a ship recedes from the land, a person on shore will first lose sight of the hull, then of the masts and lower parts of the sails, and lastly of the topsails, gradually from bottom to top; and when a ship approaches the land, a spectator on shore first discovers the upper parts of the masts and sails, and then by degrees the lower parts and the hull, in proportion as the vessel comes nearer to the shore.

Fig. 9.



It will be plain by fig. 9, that were the ship *a* elevated, so that the hull should be on a horizontal line with the eye, the whole ship would be visible instead of the topmast, there being no reason, except the convexity of the Earth, why the whole ship should not be visible at *a*, as well as at *b*.

In all these cases, the obstruction to the sight arises from the interposed water, on account of the universal convexity of the surface.

3. It has been well ascertained that eclipses of the Moon are occasioned by the Earth's shadow upon the Moon; but in all eclipses, notwithstanding the various positions of the Earth, this shadow is always circular; which is another proof that the Earth is a globe.

4. Another decisive argument is derived from observing the altitude of the north polar star, after travelling north and south a considerable number of miles; and generally, in travelling any great distance towards the north, the northern stars appear more elevated as we approach them, and the southern stars more depressed as we recede from them towards the north. When travelling towards the south, the southern stars become elevated, and the northern depressed. Were the Earth an extended plane, such changes in the positions of the fixed stars could never take place.

Many other reasons, suggested by philosophers, might here be enumerated to prove the rotundity of the Earth, had we sufficient room and inclination to take up the reader's time with the relation of them; for a very little attention, and a very little observation in travelling either by sea or land, must soon convince any reflecting person that the Earth is of a globular form. Indeed, there is not even one solitary appearance, either in the whole celestial sphere or throughout the surface of the Earth, that seems in the slightest degree to favour the idea of the Earth's being an extended plane, or of any other figure than that of a globe.

5. The figure of the Earth is not, however, perfectly spherical—both theory and experience have shown that it is *very nearly* an oblate spheroid, somewhat raised or elevated about the equatorial parts, and flattened or depressed about the poles, and the difference between the equatorial and polar diameters, according to the latest and most accurate measurements, is about 26 miles, its mean diameter being about 7,920 miles, and its circumference 24,880 miles.

Illustrate this by fig. 9. What are the real figure, diameter, and circumference of the Earth?

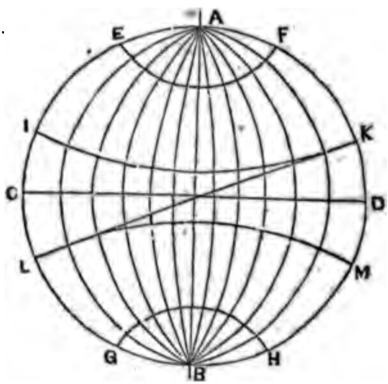
LXXVIII. A sphere, on the surface of which the various regions of the Earth are geographically depicted, or on which the fixed stars and constellations are represented, according to their apparent places in the concave surface of the heavens, is usually called an *Artificial Globe.*

Observation. Artificial globes are of two kinds, *Terrestrial* and *Celestial;* and are commonly made for the purpose of aiding the understanding, in the easy solution of several astronomical problems, and of instructing students in Astronomy and Geography. They serve to give a lively representation of their principal objects; but the lines and figures on both globes, are necessarily imaginary.

DEFINITIONS RELATING TO THE TERRESTRIAL GLOBE.

LXXIX. The *Axis* of the Earth is an imaginary line passing through the centre north and south, about which the diurnal revolution is represented by the line between A and B, fig. 10.

Fig. 10.



LXXX. The *Poles* of the Earth are the extremities of the axis, A B.

LXXVIII. What is an Artificial globe? Into how many kinds are artificial globes distinguished? What is their use? LXXIX. What is the Axis of the Earth? LXXX. What are the Poles?

LXXXI. The *Equator* is the circumference of an imaginary circle, passing round the Earth from east to west, perpendicular to the axis, and at equal distances from the poles; as the line C D.

LXXXII. The small circle E F, is called the *Arctic circle;* the circle G H, is called the *Antarctic circle.*

LXXXIII. The circle north of the equator I K, is called the *Tropic of Cancer,* that south of the equator L M, the *Tropic of Capricorn.*

LXXXIV. The spaces between the ends north and south of the equator, are called *Zones:*—that space between the tropics is called the *Torrid Zone;* those between the tropics and the polar circles, are called the *Temperate Zones;* and those to the north of the arctic and south of the antarctic circles, are called the *Frigid Zones.*

LXXXV. *Latitude* is distance north or south of the equator; *Longitude* is distance east or west measured upon the equator, from any assumed point.

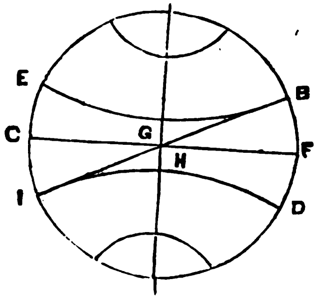
Astronomical circles, whether great or small, are mathematically divided into 360 equal parts called degrees:—of course, the length of a degree depends upon the magnitude of the circle; a degree on the surface of the Earth is about 69½ miles.

DEFINITIONS RELATIVE TO THE CELESTIAL GLOBE.

LXXXVI. Since the stars, &c., are represented on a convex surface, whereas their natural appearance is in a concave one, therefore, in using the celestial globe, the student is supposed to be situated in the centre of it, and viewing the stars in the concave surface.

LXXXI. What is the Equator? LXXXII. What are the Arctic and Antarctic circles? LXXXIII. What are the Tropics? LXXXIV. What are the Zones, and how are they distinguished with regard to different portions of the Earth's surface? LXXXV. What is Latitude; and what is Longitude? How is the circumference of every circle supposed to be divided? LXXXVI. What is observed concerning the use of a celestial globe?

Fig. 11.



LXXXVII. The line E B, fig. 11, is the *Tropic of Cancer*. The line I D, is the *Tropic of Capricorn ;* the Sun never goes north of Cancer nor south of Capricorn.

LXXXVIII. The line C F, is the *Equator* or *Equinoctial Line.*

LXXXIX. The line B I, is the *Ecliptic,* and indicates the path that the Sun appears annually to pursue in the heavens. It is divided into 12 equal parts, called *Signs of the Ecliptic.*

XC. The points at which the ecliptic intersects the equinoctial at G H, are called the *Equinoctial Points* or *Equinoxes.*

XCI. Those two points of the ecliptic farthest from the equinoctial are called *Solstices* or *Solstitial Points.*

XCII. That space in the heavens about 16 degrees in width, through the middle of which passes the ecliptic, is called the *Zodiac.*

XCIII. The *Latitude* of a heavenly body is its distance from the ecliptic ; *Longitude* is distance from the first degree of Aries.

LXXXVII. What is the Tropic of Cancer, and what the Tropic of Capricorn? LXXXVIII. What is the Equinoctial or Celestial Equator? LXXXIX. What is the Ecliptic, and how is it divided? XC. What are the Equinoctial Points? XCI. What are the Solstitial Points? XCIII. What is the Latitude of a celestial body? What is the Longitude of a celestial body?

XCIV. The *Sensible Horizon* is an imaginary circle, which appears to touch the surface of the Earth, and separate the visible part of the heavens from the invisible. The *Rational Horizon* is a circle parallel to the former, the plane of which passes through the centre of the Earth, and divides the heavens into two equal hemispheres.

XCV. The *Poles of the Horizon* are two points, the one of which, over the head of the spectator, is called the *Zenith*; the other, which is under his feet, is called the *Nadir*.

XCVI. A circle which passes from north to south through the zenith of any place, is called the *Meridian*, and is said to be the meridian of that place. The meridian of any place passing through the poles, and falling perpendicularly upon the horizon, intersects it in two opposite cardinal points, called *North* and *South*.

XCVII. The *Altitude* of any heavenly body above the horizon is the part of a vertical circle intercepted between the body and the horizon, or the angle at the centre of the Earth measured by that arc.

XCVIII. The *Azimuth* of a heavenly body, is the arc of the horizon intercepted between the meridian and a vertical circle passing through that body; it is eastern or western as the body is east or west of the meridian.

XCIX. The *Amplitude* of a heavenly body at its rising or setting, is the arc of the horizon intercepted between the point where the body rises, and the east or west.

C. The *Declination* of any heavenly body, is its distance from the equinoctial, and is either northern or southern.

CI. The *Right Ascension* of any heavenly body, is its distance from the first of Aries reckoned upon the equinoctial.

XCIX. What is meant by the Sensible Horizon, and what by the Rational or True Horizon? XCV. What are the Poles of the Horizon, and what are they called? XCVI. What is meant by Meridian? XCVII. What is meant by the Altitude, Azimuth, and Amplitude of a celestial body? C. What is meant by Declination? CI. What is meant by Right Ascension?

CII. A planet's place, considered as seen from the Sun, is called its *Heliocentric* place, and as seen from the Earth, its *Geocentric* place.

CIII. Two planets are said to be in *Conjunction* with each other when they have the same longitude, or are in the same degree of the ecliptic on the same side of the heavens, though their latitude may be different. They are said to be in *Opposition* when their longitudes differ half a circle, or they are in opposite sides of the heavens. See fig. 2, and Prop. xi.

CIV. The celestial sphere is called *Right*, *Oblique*, or *Parallel*, as the equator is at right angles, oblique or paralled to the horizon.

CV. As the Earth revolves round its axis daily from west to east, the heavenly bodies appear to a spectator on the Earth to revolve in the same time from east to west, and the alternate succession of day and night is the effect of the revolution of the Earth towards and from the Sun.

Observation 1. For all the heavenly bodies appearing to move from east to west, while the Earth revolves from west to east, the Sun will appear in each revolution, to rise above the horizon in the east, and after describing a portion of a circle, to set in the west, and will continue below the horizon, till, by the revolution of the Earth, it again appears in the east; and thus day and night are alternately produced.

2. Further, as any meridian will, by the diurnal motion of the Earth, revolve from the Sun to the Sun again in 24 hours, and as only one half of the Earth can be enlightened at a time, it is evident that any particular place will sometimes be turned toward the Sun, and sometimes from it, and being constantly subject to these various positions, will be subject to a regular succession of light and darkness; as long as the place continues in the enlightened hemisphere, it will be day; and when, by the diurnal rotation of the Earth, the place is carried into the dark hemisphere, it will be night.

CVI. As the Earth revolves round the Sun in 365 days, 6 hours, 9 minutes, 11½ seconds, the Sun appears to revolve round the Earth in the same time, but in the contrary direction.

Observation 1. It is manifest that the circle in which the Sun appears to move, is the same as that in which the Earth would appear to move to a

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CII. What is to be understood by Heliocentric place, and what by Geocentric place? CIII. When are two celestial bodies said to be in Conjunction, and when in Opposition? CIV. What is signified by Right, Oblique or Parallel spheres? CV. In what manner is the alternate succession of day and night produced? CVI. In what length of time does the Earth perform a revolution round the Sun?

spectator in the Sun. Hence, the apparent place of the Sun being found, the true place of the Earth in its orbit is known to be 180° distant.

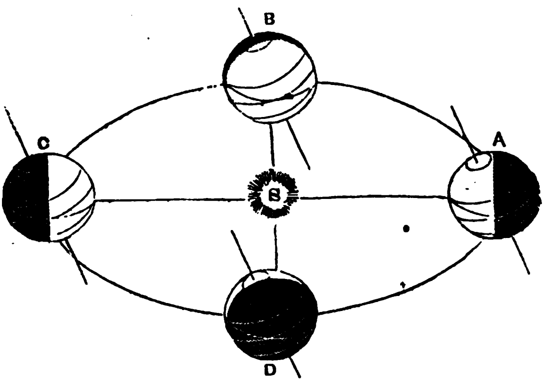
2. The orbit in which the Earth revolves round the Sun is not a circle but an ellipse, having the Sun in one of its foci. For, the computations of the Sun's place, upon this supposition, allowing for the disturbing forces of the planets are found to agree with observations.

CVII. The annual revolution of the Earth, in common with the rest of the planets, round the Sun, is in popular language, from *west*, by *south* to *east;* or to speak more philosophically, it is according to the *Order of the Signs ;* and the same thing may be affirmed with respect to the diurnal rotation.

CVIII. The axis of the Earth, in every part of the Earth's revolution about the Sun, makes with the plane of its orb, that is, of the ecliptic, an angle of about 66° 32′ ; consequently the planes of the equator and ecliptic, make with each other an angle of 23½°.

Illustration. Suppose A, B, C, D, fig. 12, four different positions of an artificial globe, with a wire running through each as an axis, and the elliptical line to represent the surface of a table which also represents the plane of the ecliptic, while S represents a lamp in the centre of the table, or the Sun in the centre of the system.

Fig. 12.



CVII. In what direction is the annual and diurnal motion of the Earth? CVIII What is the quantity of the angle formed by the inclination of the ecliptic to the equinoctial? Describe the obliquity of the ecliptic by the diagram.

Now let the wires of the globes be so inclined to the surface of the table, as to form an angle with it of 66° and 32′; here the wires represent the axis of the earth, and the surface of the table, the plane of the ecliptic. The axis will consequently form an angle with a perpendicular to the table of 23° 30′.

At the wires or axes, all the several positions are equally inclined to the plane of the ecliptic, they are parallel each with each, and thus properly represent the position of the Earth in different parts of its orbit with regard to the same. While at A, the Sun shines vertically at the northern tropic its farthest point from the equator, while at C, it shines vertically on the southern tropic; the former corresponding with our midsummer, and the latter with our winter—the position at B, will be that of autumn, while C corresponds with spring.

Observation 1. The obliquity of the ecliptic is not permanent, but is continually diminishing by the ecliptic's approaching nearer to a parellism with the equinoctial, at the rate of about half a second in a year, or from 50″ to 55″ in 100 years.—The inclination on January 1, 1815, was 23° 27′ 46″ nearly. The diminution of the obliquity of the ecliptic to the equinoctial, is owing to the action of the planets upon the Earth, especially Venus and Jupiter. The whole diminution, it is said, can never exceed 1°, when it will again increase.

2. According to the calculations of La Grange, the obliquity of the ecliptic has diminished during 2000 years, and will diminish during 2000 more; and Schubert has determined its limits at 20° 34′, and 27° 48′. Its variation at present is 50″ in a century. The change of obliquity will never exceed a certain limit, as is shown by Physical Astronomy; which limit, according to *Laplace*, is 2° 42′.

3. The diminution of the obliquity of the ecliptic is a consequence of the approach of the Earth's axis towards a perpendicular direction to the plane of the Ecliptic; but the Earth's axis has, besides the progressive motion, a tremulous one, by which its inclination to the plane of the ecliptic varies backward and forward some seconds; the period of these variations is nine years. The tremulous motion is termed the *Nutation* of the Earth's axis. Both these motions of the terrestrial axis are occasioned by the action of the Sun, Moon and planets, on the Earth.

CIX. The axis of the heavens is perpendicular to the planes of all the circles which the celestial bodies seem to describe in their apparent diurnal motions. For all the celestial bodies, from the rotation of the Earth on its axis, appear to move from east to west in circles perpendicular to the axis.

Observation 1. Hence it is evident that the planes of all the circles of apparent daily motion are parallel to the equator and equinoctial, and that the celestial axis passes through the centres of those circles.

2. When the Sun, or any other celestial body is in the equinoctial, it rises

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What is said concerning the permanency of the obliquity of the ecliptic? From what cause does the diminution of the obliquity of the ecliptic arise? What is the Nutation of the Earth's axis, and by what is it occasioned? CIX. What is observed concerning the perpendicularity of the Earth's axis to the planes of all the circles of apparent diurnal motion? At what time does the Sun rise in the east and set in the west?

in the east and sets in the west. For it then rises and sets in the points in which the equinoctial intersects the horizon; that is, because the equinoctial is at right angles to the meridian, which passes through the north and south points, in the points of east and west.

In north latitude, those celestial bodies which have north declination, rise between the east and north; and those which have south declination, rise between the east and south.

CX. Those inhabitants who live at the equator are in a right sphere; and, consequently, their days and nights are always equal.

Observation 1. An inhabitant at either of the poles of the Earth would be in a parallelsphere; he would see all the celestial bodies apparently revolving round him in circles parallel to the horizon, and his day and night would continue each a half a year.

2. But those who live on any part of the surface of the Earth, between the equator and either pole, are in an oblique sphere, and have all the circles of daily motion oblique to their horizon.

CXI. When the Sun, in its apparent annual course, is in the points in which the ecliptic intersects the equinoctial, the day and night will be of the same length at all places on the surface of the Earth; but when the Sun is in any other part of the ecliptic, the days will be longer, as the Sun's declination towards the elevated pole increases, and shorter as its declination towards the depressed pole increases.

Observation. All those celestial bodies which are at any time on the same side of the equinoctial with the spectator, continue longer above the horizon than below it, and *vice versa.*

CXII. At different places, the hour of the day differs in proportion to the difference of longitude; 15 degrees of longitude making the difference of one hour in time, $15'$ one minute of time, $15''$ one second of time; and a celestial appearance is seen at any given place sooner than at places which are situated to the west of it, and later at places which are situated to the east of it.

Observation. The Sun in its apparent diurnal motion, which is from east to west, must arrive at the meridian of any given place, as New York, sooner than it will arrive at the meridian of any place which is situated to the west of New

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In what direction do those celestial bodies rise which have northern declination? CX. What is said concerning the celestial phenomena in a right sphere? in a parallel sphere, and in an oblique sphere? CXI. When are the days and nights equal, and when unequal? CXII. How does the hour of the day differ at different places? What is the reason of that difference?

York, and later than at the meridian of any place to the east of New York; that is, since it is noon at any place where the Sun is in its meridian, it will be noon sooner at New York than at places west, and later than at places east of New York.

CXIII. The difference of longitude at two places, may be found by observing, at the same time from both places, some simultaneous appearance in the heavens.

Observation. If the eclipse of Jupiter's innermost satellite, on the very instant of its immersion into the shadow of Jupiter, be observed by two persons at different places, it will be seen by both at the same instant. But if this instant, with reference to the day, be half an hour, for example, sooner at one place than at the other, because the places differ half an hour in their reckoning of time, their difference of longitude must be 7° 30′; because the whole 360° are equal to 24 hours, and consequently every 15° are equal to an hour.

CXIV. The inhabitants of the Earth have different names assigned to them by geographers, according to the several meridians and parallels of latitude under which they live, and are called *Periœci*, *Antœci* and *Antipodes*.

CXV. Those who live on opposite sides of the Earth, but in the same parallel of latitude, have opposite hours of the day, but the same seasons.

Observation. Being both on the same side of the equator and at the same distance from it, when the Sun's declination makes it summer or winter in one of the places, it will be the same at the other; but because they are distant from each other 180° of longitude, when it is noon at one place, it is midnight at the other; these are called *Periœci.*

CXVI. Those who live in opposite parallels of latitude, but under the same meridian, have opposite seasons of the year, but the same hour of the day.

Observation. When the Sun has its declination towards the north pole, it will be summer to those who live in the northern parallel of latitude, and winter to those who live in the southern parallel of latitude. But having the same longitude, their hours of the day will be the same; these are called *Antœci.*

CXVII. Those who live in opposite parellels of latitude and opposite semicircles of the meridian, have opposite seasons of the year, and opposite hours of the day.

CXIII. In what manner may the difference of longitude at two places be ascertained? How is the manner of ascertaining the difference of longitude at two places explained? CXIV. How are the inhabitants of the Earth denominated according to their several situations on the surface? CXV. What are the Periœci. CXVI. What are Antœci? CXVII. What are Antipodes?

Observation 1. Because they are in opposite latitudes, they will have opposite seasons; and because they are in opposite semicircles of the meridian, they will have noon when it is midnight at the other place; these are called *Antipodes*.

2. These and many other propositions will be more readily and clearly understood by means of Artificial Globes and the problems on the globes, &c. (See Ryan's New American Grammar of Astronomy; Treeby's Elements of Astronomy; and other works.)

CXVIII. The axis of the Earth, in its circuit round the Sun, being inclined to the plane or level of its orbit, this inclination occasions the succession of the four seasons.

Observation 1. It has already been shown that the alternate succession of day and night is produced merely by the simple uniform rotation of the Earth upon its axis, as must be evident upon a moment's reflection; but the different lengths of days and nights, in every part of the world, in the course of the year, and the phenomena of the different seasons, or those delightful changes which we constantly experience, of heat and cold, summer and winter, spring and autumn, are occasioned by the annual revolution of the Earth about the Sun, in the plane of the ecliptic.

2. As the Earth's axis makes an angle of 66° 32′ with its orbit, that is, with the ecliptic, and always preserves its parellelism, it is directed towards the same point, at an infinite distance in the heavens; hence, during one half of the year, the north pole is continually illuminated by the Sun, and the south pole is all that time in darkness; and during the other half of the year, the south pole is constantly in the light, and the north pole is in darkness; and other parts in a proportional degree partake of this vicissitude, and create the variety of the seasons.

3. The difference in the degrees of heat, is owing chiefly to the different heights to which the Sun rises above the horizon and the different length of the days. When the Sun rises highest in summer, its rays fall less obliquely, and consequently more of them fall on any given portion of the Earth's surface than in winter, when the rays fall obliquely; and when the days are long, and the nights short, the Earth and air are more heated in the day than they are cooled in the night, and the reverse when the days are short and the nights long.

Observation. It has already been explained, that the ecliptic is the plane of the Earth's orbit, and is supposed to be placed on a level with the Earth's horizon, and hence, that this plane is considered the standard, by which the inclination of the lines crossing the Earth, and the obliquity of the orbits of the other planets, are to be estimated.

CXIX. The equinoctial line, or equator, which is the great circle surrounding the middle of the Earth, in a

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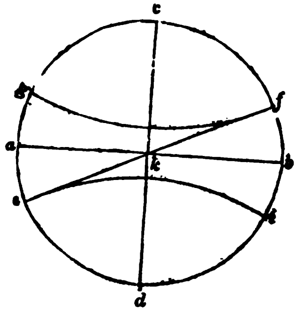
How are the several circumstances relating to them illustrated? CXVIII. What causes the variation of the seasons, and the difference in the lengths of the days and nights? How much is the axis of the Earth inclined to the plane of its orbit? What is the cause of the difference in the degrees of heat? CXIX. In what position is the equator, with respect to the ecliptic?

direction east and west, intersects or crosses the plane of the ecliptic in two opposite points of the globe.

Illustration. Let *e f*, fig. 13, represent the ecliptic, and *a b*, the equator; then *c d* will be the axis, *e k* the southern, and *g f* the northern tropic. Now it is evident that as the circle *e f*, here seen edgewise goes quite around the Earth, and as *a b* also goes around the Earth, *a b* and *e f* must cross each other, not only on this side at *k*, but also on the other side at a point exactly opposite to *k*: but it will be recollected that the great circle *e f* is not a circle around the Earth, but is the annual path of the Earth in its revolution around the Sun, hence this circle is made once every year.

Fig. 13.



CXX. The periods when the ecliptic crosses the equator, or, as expressed more generally, when the Sun crosses the line, are called the *equinoxes*, the places are called the *equinoctial points*. These periods occur, one on the 21st of March, called the *vernal equinox*, and the other on the 21st of September, called the *autumnal equinox*, at which times the days and nights are of equal length in every part of the Earth.

CXXI. The solstices are those two places in the ecliptic farthest from the equator; or they are the extreme limits of the vertical rays of the Sun, and correspond in latitude with the tropics, being 23° 30′ north and south of the

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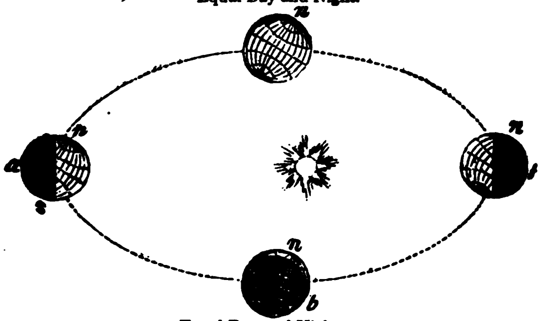
CXX. At what times in the year do the line of the ecliptic and that of the equinox intersect each other? What are these points of intersection called? Which is the autumnal, and which the vernal equinox? At what time does the Sun rise and set, when he is in the equinoxes? CXXI. What are the solstices?

equator. The northern or *summer* solstice occurs on the 21st of June when our days are the longest, and the southern or *winter* solstice occurs on the 21st of December, when our days are the shortest, and of course the nights longest.

Observation. The student will now be able to understand in what order the seasons succeed each other, and the reasons why such changes are the effect of the Earth's revolution.

Fig. 14.

Equal Day and Night.



Equal Day and Night.

Illustration 1. Fig. 14 is a diagram representing the position of the Earth in its orbit with regard to the Sun, in the four seasons for illustrating their succession as well as that of day and night. Let *a* represent the Earth in her summer solstice, about the 21st of June, when the north pole *n* will be so much inclined towards the Sun, that his rays will penetrate 23½ degrees beyond the pole and the whole arctic circle will be illuminated with perpetual day, during which time, the whole antarctic circle will be in continual darkness. If we proceed a little south of the arctic circle we shall find that there will be an increase of light, according to the distance from the circle, and a decrease in the length of day until we reach the equator, where the days and nights are equal. During the same time that the days are longer than the nights in the northern hemisphere, the nights are as much longer than the days in the southern hemisphere.

2. We will now suppose the Earth to have moved on in her annual course

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When the Sun enters the summer solstice, what is said of the length of the days and nights? When does the Sun enter the winter solstice, and what is the proportion between the length of the days and nights? At what season of the year is the whole arctic circle illuminated? At what season is the whole antarctic circle in the dark? While the people near the north pole enjoy perpetual day, what is the situation of those near the south pole?

from *a* to *b*, where she arrives at the autumnal equinox, or on the 21st of September at which time the Sun's rays fall vertically on the equator and reach both poles, so that the nights and days are equal in every part of the globe, each being 12 hours.

It will be recollected by the pupil that it is only during the time of the equinoxes that the Sun's rays fall perpendicularly on the equator, for at all other times they are oblique to it. The duration of the equinox is but a point of time, inasmuch as the Sun, to use the common language, does not remain for a moment on the equator, but moves rapidly across it.

3. In the third position of the Earth, it has moved on in its orbit from *b* to *f*, where it arrives the 21st of December, or at the time of the *winter solstice*, when the northern or arctic circle is entirely obscured and the whole antarctic circle is equally illuminated. The rays of the Sun now fall perpendicularly on the tropic of capricorn, causing summer in the southern, and winter in the northern hemisphere.

4. The fourth position of the Earth, having moved from *f* around to *n* on the upper part of the diagram, is in that part of her orbit, where she arrives on the 21st of March, and which position is called the the *vernal equinox*. Here the Sun's rays are vertical on the equator, and both poles are enlightened and the days and nights are again equal in every part of the earth.

5. From *n* the last position of the Earth just described, it returns to *a*, the original starting-place, during which movement more and more of the northern hemisphere becomes illuminated, and more of the southern becomes obscured until it reaches the point *a*, where the Sun's rays again fall perpendicularly upon the tropic of Cancer at which time we have the longest days and shortest nights in the northern hemisphere.

6. It appears from the remarks already made that the motion of the Earth in its orbit, is the cause of an apparent motion of the Sun in a contrary direction; hence also the ecliptic as already defined, is the real path of the Earth, but the apparent path of the Sun.

7. Contrary to what might have been expected we find that the hottest seasons at the tropics, are not the exact time when the Sun's rays are vertical there, but nearly a month later; and the coldest season, is also nearly a month after the shortest days, or the time when the Sun's rays are most oblique at the tropics. This effect arises from the fact, that the Earth on the approach of summer, in the given place continues to accumulate heat, for some time after the rays have ceased to be vertical there, and so in the winter, on the approach and after the access of the shortest days, the Earth radiates more heat than it receives from the Sun, which produces an increase of cold till a month after the shortest days.

CXXII. It has been ascertained that the Earth moves on in its orbit, at the rate of 68,000 miles an hour. Its movement on its axis to those inhabitants about the equa-

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At what season will the days be longer than the nights every where between the equator and the arctic circle? At what season will the nights be be longer than the days in the southern hemisphere? When will the days and nights be equal in all parts of the Earth? At what season of the year is the whole arctic circle involved in darkness? When are the days and nights equal all over the world? When is the Sun in the vernal equinox? What is the cause of the apparent motion of the Sun from east to west. What is the apparent path of the Sun, but the real path of the Earth? What is said of the hottest and coldest days in the years?

tor, is at the rate of about 1040 miles per hour. Our motion therefore in the Earth's orbit is *one million six hundred and thirty-two thousand miles* per day, while our motion from the rotation is at the rate of *twenty-five thousand miles* per day.

Observation. These motions and rates of motion are ascertained as follows:—That of the Earth in its orbit, is obtained from knowing the diameter and circumference of the orbit, and dividing the distance by the number of days in the year, which will give the space passed through in its orbit each days; and the circumference of the Earth, would constitute the space through which an inhabitant near the equator would pass per day, from the rotary motion of the Earth.

CXXIII. The motion of the Earth in her orbit, as well as that from rotation, is not perceived by us, because all terrestrial objects have the same motion; and with none of these can we compare this motion.

Illustration. If there were other objects stationary near the Earth which we could view by passing them, we should then perceive that one of the bodies was in motion, but we might not be able to say which it was; this remark is applicable to persons sailing in a ship, or riding in a carriage, where land, trees, houses, &c., seem to be moving in a direction opposite to that in which we go. By carefully watching the Sun or Moon, we can perceive them to be in apparent motion.

CXXIV. *Summer and Winter.* The cold of winter is caused, not as might naturally be supposed by the difference of distance from the Sun from us in summer and in winter, for he is really nearer us in winter than in summer; but by the greater obliquity of his rays, as they fall upon the Earth, in winter than in summer.

Observation. The direction in which the Sun's rays fall upon the Earth, in summer and in winter, may be learned by inspecting the diagram figure 15 (p. 218) where we have the Earth represented as receiving pencils of the Sun's rays, from two different points in the heavens. In the position of the Sun, on the right hand the rays fall nearly perpendicular upon the Earth, while those from the position on the left fall very obliquely, and as seen by inspection of the figure, are spread over nearly twice the space, the necessary consequence of which is that more rays will be received in any given area, where the rays fall perpendicularly, than when they fall obliquely and of course more heat will be produced where these rays strike the Earth. It

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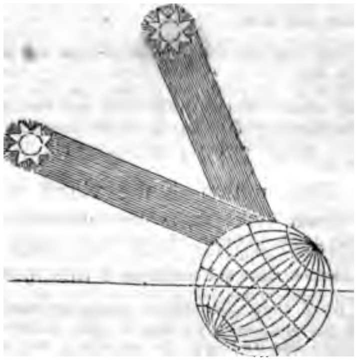
CXXII. At what rate does the Earth move around the Sun? How fast does it move around its axis at the equator? How is the velocity of the Earth ascertained? CXXIII. Why are we insensible of the Earth's motion? CXXIV. Define the cause of cold and heat of summer and winter. How are the principles explained? Give the illustration.

is well known that the Sun's rays fall much more obliquely on the northern hemisphere in winter than in the summer, which is a sufficient explanation of the difference of temperature experienced.

Fig. 15.



It may, however, be remarked, that the hottest season is not usually at the exact time of the year, when the Sun is most vertical, and the days the longest, as is the case towards the end of June, but some time afterward, as in July and August.

To account for this, it must be remembered, that when the Sun is nearly vertical, the Earth accumulates more heat by day than it gives out at night, and that this accumulation continues to increase after the days begin to shorten, and consequently, the greatest elevation of temperature is some time after the longest days. For the same reason, the thermometer generally indicates the greatest degree of heat at 2 or 3 o'clock on each day, and not at 12 o'clock, when the Sun's rays are most powerful.

CXXV. *Twilight* is occasioned by the atmosphere above the horizon reflecting rays of the Sun, when the Sun itself is below the horizon.

Observation 1. When the Sun is at any point below the horizon, it cannot be directly seen by a spectator. But, because rays from the Sun can pass to the part of the atmosphere above the head of the spectator, this part of the atmosphere will be illuminated before the Sun rises, or after it sets, and will become visible by reflection to the spectator; that is, *twilight* will be produced.

2. It is entirely owing to the reflection of the atmosphere that the heavens appear bright in the daytime. For, without it, only that part would be luminous in which the Sun is placed; and if we could live without air, and should turn our backs to the Sun, the whole heavens would appear as dark

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CXXV. What is the cause of twilight? How is the phenomenon explained? What would be the consequence if the atmosphere were annihilated?

as in the night. In this case also we should have no twilight, but a sudden transition from the brightest sunshine to dark night immediately after the setting of the Sun.

3. The *twilight* is longest in a parallel sphere, and shortest in a right sphere; and in an oblique sphere, the nearer the sphere approaches to a parallel, the longer is the twilight, because twilight lasts till the Sun is 18° perpendicularly below the horizon.

CXXVI. The atmosphere also refracts the Sun's rays in such a manner, as to bring that luminary into sight every clear day, before it rises in the horizon, and to keep it in view for some minutes after it is really set below the horizon. The effect of this refraction in a right sphere is about two minutes of time, or 33′ of space, being rather more than the diameter of the Sun or Moon.

Observation 1. From the same cause, all the heavenly bodies appear higher than they really are, so that to bring the apparent altitudes to the true ones, the quantity of refraction must be subtracted. The higher they rise the less are the rays refracted, and when the heavenly bodies are in the zenith, they suffer no refraction.

2. When the evening twilight ends, or the morning twilight begins, a ray of light from the Sun, reflected from the highest part of the atmosphere, describes after reflection, a line which is in the plane of the sensible horizon.

CXXVII. A *Natural Day* is the time the Sun takes in passing from the meridian of any place, till it comes round to the same meridian again; but the natural days are not equal to each other; and the *Equation of Time*, is the difference between the mean length of the natural day or 24 hours, and the length of any single day measured by the Sun's apparent motion, or between *mean time* and *apparent time*.

Observation 1. For any natural day is the time in which the Earth performs one revolution on its axis, and such a portion of a second revolution as is equal to the Sun's increments of right ascension for that day; but the Sun's daily increments of right ascension are unequal; therefore the additional portion of the second revolution will sometimes be greater and sometimes less, and consequently, the times in which the natural days are completed will be unequal.

2. If the Sun were to move uniformly round the equinoctial in the same time in which it appears to describe the ecliptic, its apparent daily motion would be a measure of mean time. For the natural days in that case being liable to no variation, either from the inclination of the Sun's apparent orbit, or the irregularity of its motion, must be equal.

Where is the twilight longest and shortest? CXXVI. What effect does the atmosphere have on the Sun's rays? Why do we see the Sun or a star before it is really above the horizon at rising; and after it is below the horizon at setting? CXXVII. What is a Natural Day? What is the Equation of Time? What is meant by mean time and apparent time?

THE MOON.

CXXVIII. There is no object within the scope of astronomical observation which affords greater variety of interesting investigation than the various phases and motions of the Moon. From them the astronomer ascertains the form of the Earth, the vicissitudes of the tides, the causes of eclipses and occultations, the distance of the Sun, and consequently, the magnitude of the solar system.

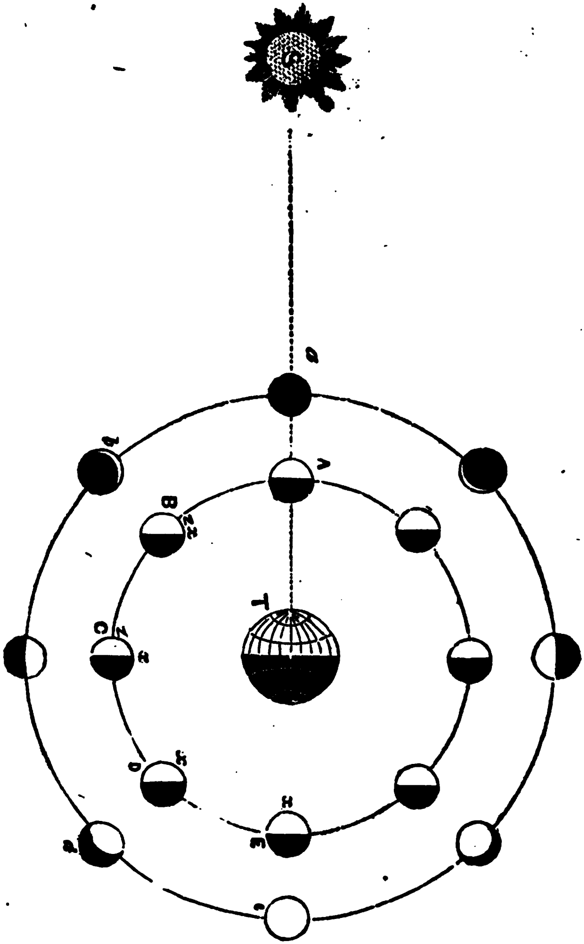
CXXIX. When the Moon, after having been in conjunction with the Sun, emerges from his rays, she first appears in the evening, a little after sunset, like a fine luminous crescent with its convex side towards the Sun. If we observe her the next evening, we find her about 13° farther east of the Sun than on the preceding evening, and her crescent of light sensibly augmented. Repeating the e observations, we perceive that she departs farther and farther from the Sun, as her enlightened surface comes more and more into view, until she arrives at her *first quarter*, and comes to the meridian at sunset. She has then finished half her course from the the new to the full, and half her enlightened hemisphere is turned towards the Earth.

After her first quarter, she appears more and more *gibbous*, as she recedes farther and farther from the Sun, until she has completed just half her revolution around the Earth, and is seen rising in the east when the Sun is setting in the west. She then presents her enlightened orb *full* to our view, and is said to be in *opposition;* because she is then on the opposite side of the Earth with respect to the Sun.

In the first half of her orbit she appears to pass over our heads through the upper hemisphere; she now descends below the eastern horizon to pass through that part of her orbit which lies in the lower hemisphere.

After her full, she wanes through the same changes of

CXXVIII. What important purposes does the Moon serve to the astronomer? Describe the apparent motions of the Moon and her phases.



THE MOON'S PHASES.
Fig. 16.

appearance as before, but in an inverted order; and we see her in the morning like a fine thread of light, a little west of the rising-sun. For the next two or three days she is lost to our view, rising and setting in *conjunction* with the Sun; after which she passes over, by reason of her daily motion, to the *east* side of the Sun, and we behold her again a new Moon, as before. In changing sides with the Sun, she changes also the direction of her crescent. Before her conjunction, it was turned to the east. it is now turned towards the west.

CXXX. These different appearances of the Moon are called her *phases*. They prove that she shines not by any light of her own; if she did, being globular, we should always see her a round full orb like the Sun.

Illustration. The various phases of the Moon may be understood by inspecting the woodcut, fig. 16, page 221.

In fig. 16, S is the the Sun, T the Earth, A B C, &c., the Moon in its orbit. One half of the Moon is always enlightened by the Sun. At A, the Moon is between the Earth and Sun, it is then *new;* and is invisible as represented at *a*; at B the enlightened part *x z* is turned to the Earth, and it appears horned as at *b*; at C the half of the enlightened side is turned to the Earth, and it appears a half moon as at *c*; at D the part *x z* is turned to the Earth, and it appears as at *d*; and at E the whole of the enlightened part of the Moon is turned to the Earth, and we have full moon as at *e*. As it passes through the rest of the orbit, it puts on the same phases as before, but in a contrary order.

CXXXI. The Moon is a satellite to the Earth, about which she revolves in an elliptical orbit, in 29 days, 12 hours, 44 minutes, and 3 seconds; the time which elapses between one new Moon and another. This is called her *synodical* revolution. Her revolution from any fixed star to the same star again, is called her *periodic* or *sidereal* revolution. It is accomplished in 27 days, 7 hours, 43 minutes and 11½ seconds; but in this time, the Earth has advanced nearly as many *degrees* in her orbit; consequently the Moon, at the end of one complete revolution, must go as many degrees farther, before she will come

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CXXX. How is it known that the Moon does not shine by her own light? CXXXI. About what does the Moon revolve, and what is the figure of her orbit? What is the time of her revolution from one new Moon to another? What is this revolution denominated? What is her periodic or sidereal revolution? In what time is this accomplished?

again into the same position with respect to the Sun and the Earth.

CXXXII. The Moon is the nearest of all the heavenly bodies, being about 30 times the diameter of the Earth, or 240,000 miles distant from us. Her mean daily motion, in her orbit, is nearly 14 times as great as the Earth's; since she not only accompanies the Earth around the Sun every year, but in the meantime, performs nearly 13 revolutions about the Earth.

CXXXIII. The Moon, though apparently as large as the Sun, is the smallest of all the heavenly bodies that are visible to the naked eye. Her diameter is but 2162 miles; consequently her surface is 13 times less than that of the Earth, and her bulk 49 times less. It would require 70,000,000 of such bodies to equal the volume of the Sun. The reason why she appears as large as the Sun, when, in truth, she is so much less, is because she is 400 times nearer to us than the Sun is.

CXXXIV. The Moon revolves once on her axis exactly in the time that she performs her revolution around the Earth. This is evident from her always presenting the same side to the Earth; for if she had no rotation upon her axis, every part of her surface would be presented to a spectator on the Earth, in the course of her synodical revolution. It follows, then, that there is but *one day and night in her year*, containing both together, 29 days, 12 hours, 44 minutes and 3 seconds.

CXXXV. As the Moon turns on her axis only as she moves around the Earth, it is plain that the inhabitants of

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To what is the difference of time in these two revolutions owing? CXXXII. How great is the distance of the Moon from the Earth compared with that of the other heavenly bodies? What is her distance from us? What is her motion in her orbit, compared with the Earth's? How many times does she revolve around the Earth, every year? CXXXIII. What is her magnitude, compared with that of the other heavenly bodies? What is her diameter? How great are her surface and her bulk, compared with those of the Earth? How many such bodies would it require to equal the volume of the Sun? Why does she appear as large as the Sun, when in reality she is so much less? CXXXIV. What is the time of her revolution on her axis, compared with that of her revolution around the Earth? How is this proved? How many days and nights then has she in the course of her synodical revolution? What is the length of both united? CXXXV. Describe the phenomena of the Earth as seen by the inhabitants of the Moon

one half of the lunar world are totally deprived of the sight of the Earth, unless they travel to the opposite hemisphere. This we may presume they will do, were it only to view so sublime a spectacle; for it is certain that the Earth appears to the Moon *ten times larger* than any other body in the universe.

As the Moon enlightens the Earth, by reflecting the light of the Sun, so likewise the Earth illuminates the Moon, exhibiting to her the same phases that she does to us, only in a contrary order. And as the surface of the Earth is 13 times larger than that of the Moon, the Earth when full to the Moon, will appear 13 times larger than the full Moon does to us. That side of the Moon, therefore, which is towards the Earth, may be said to have no darkness at all, the Earth constantly shining upon it with extraordinary splendour when the Sun is absent; it therefore enjoys successively two weeks of illumination from the Sun, and two weeks of earth-light from the Earth. The other side of the Moon has alternately a fortnight's light, and a fortnight's darkness.

CXXXVI. As the Earth revolves on its axis, the several continents, seas and islands, appear to the lunar inhabitants like so many spots, of different forms and brightness, alternately moving over its surface, being more or less brilliant, as they are seen through intervening clouds.

CXXXVII. By these spots, the lunarians cannot only determine the period of the Earth's rotation, just as we do that of the Sun, but they may also find the longitude of their places, as we find the latitude of ours.

As the full Moon always happens when the Moon is directly opposite the Sun, all the full Moons in our *winter*, must happen when the Moon is on the *north* side of the equinoctial, because *then* the Sun is on the *south* side

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CXXXVI. As the Earth revolves on its axis, how do its continents, seas, and islands, appear to the lunar inhabitants? CXXXVII. For what purposes may these spots serve to the lunarians? What are the periods of the Moon's presence and absence to the polar inhabitants? Explain this

of it; consequently, at the north pole of the Earth, there will be a fortnight's moon-light and a fortnight's darkness by turns, for a period of six months, and the same will be the fact during the Sun's absence the other six months, at the south pole.

CXXXVIII. The Moon's axis being inclined only about $1\frac{1}{2}°$ to her orbit, she can have no sensible diversity of seasons; from which we may infer, that her atmosphere is mild and uniform. The quantity of light which we derive from the Moon when full, is at least 300,000 times less than that from the Sun.

CXXXIX. When viewed through a good telescope, the Moon presents a most wonderful and interesting aspect. Besides the large dark spots, which are visible to the naked eye, we perceive extensive valleys, shelving rocks, and long ridges of elevated mountains, projecting their shadows on the plains below. Single mountains occasionally rise to a great height, while circular hollows, more than *three miles* deep, seem excavated in the plains.

CXL. Her mountain scenery bears a striking resemblance to the towering sublimity and terrific ruggedness of the Alpine regions or of the Appenines, after which some of her mountains have been named, and of the Cordilleras of our own continent. Huge masses of rock rising precipitously from the plains, lift their peaked summits to an immense height in the air, while shapeless crags hang over with their projecting sides, and seem on the eve of being precipitated into the tremendous chasm below.

CXLI. Around the base of these frightful eminences, are strewed numerous loose and unconnected fragments, which time seems to have detached from their parent

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CXXXVIII. Why cannot the Moon have any sensible diversity of seasons? What then may we infer to be the character of her atmosphere? What is the quantity of light which she affords when full, compared with that of the Sun? CXXXIX. Describe the appearance of the Moon when seen through a good telescope. CXL. What mountains of the Earth does her mountain scenery resemble? CXLI. Describe the appearance around her mountains.

mass; and when we examine the rents and ravines which accompany the overhanging cliffs, the beholder expects every moment that they are to be torn from their base, and that the process of destructive separation which he had only contemplated in its effects, is about to be exhibited before him in all its reality.

CXLII. The range of mountains called the Appenines, which traverse a portion of the Moon's disk from northeast to southwest, and of which some parts are visible to the naked eye, rise with a precipitous and craggy front from the level of the *Mare Imbrium*, or Sea of Showers.* In this extensive range are several ridges whose summits have a perpendicular elevation of four miles and more; and though they often descend to a much lower level, they present an inaccessible barrier on the northeast, while on the southwest they sink in gentle declivity to the plains.

CXLIII. There is one remarkable feature in the Moon's surface which bears no analogy to any thing observable on the Earth. This is the circular cavities which appear in every part of her disk. Some of these immense caverns are nearly four miles deep, and forty miles in diameter. They are most numerous in the southwestern part. As they reflect the Sun's rays more copiously, they render this part of her surface more brilliant than any other. They present to us nearly the same appearance as our Earth might be supposed to present to the Moon, if all our lakes and seas were dried up.

CXLIV. The number of remarkable spots in the Moon, whose latitude and longitude have been accurately determined, exceeds 200. The number of seas and lakes,

* The name of a lunar spot.

CXLII. On what part of her disk is that range of mountains, called the Appenines, situated? Describe it. CXLIII. What remarkable feature in the Moon's surface, bears no analogy to any thing observable on the Earth's surface? Describe their appearance? CXLIV. What is the number of remarkable spots in the Moon's surface, whose latitude and longitude have been accurately determined?

as they were formerly considered, whose length and breadth are known, is between 20 and 30; while the number of peaks and mountains, whose perpendicular elevation varies from a fourth of a mile to five miles in height, and whose bases are from one to seventy miles in length, is not less than one hundred and fifty.

CXLV. Graphical views of these natural appearances, accompanied with minute and familiar descriptions, constitute what is called *Selenography*, from two Greek words, which mean the same thing in regard to the Moon, as *Geography* does in regard to the Earth.

CXLVI. An idea of some of these scenes may be formed by conceiving a plain of about 100 miles in circumference, encircled by a range of mountains, of various forms, three miles in perpendicular height, and having a mountain near the centre, whose top reaches a mile and a half above the level of the plain. From the top of this central mountain, the whole plain with all its scenery, would be distinctly visible, and the view would be bounded only by a lofty amphitheatre of mountains, rearing their summits to the sky.

CXLVII. The bright spots of the Moon are the mountainous regions; while the dark spots are the plains, or more level parts of her surface. There may be rivers or small lakes on this planet; but it is generally thought, by astronomers of the present day, that there are no seas or large collections of water, as was formerly supposed. Some of these mountains and deep valleys are visible to the naked eye; and many more are visible through a telescope of but moderate powers.

What is the number of seas and lakes, as they were formerly considered? Whose dimensions are known? What is the number of peaks and mountains whose perpendicular elevation varies from a fourth of a mile to five miles, and whose bases are from one to seventy miles in length? CXLV. Define Selenography. CXLVI. Give an illustration to enable us to form some idea of some of these scenes. CXLVII. Which spots are the mountainous regions, and which the plains? Do astronomers now suppose, as they did formerly, that there are large collections of water on the Moon's surface? Are any of her mountains and valleys visible to the naked eye?

CXLVIII. A telescope which magnifies only 100 times, will show a spot on the Moon's surface, whose diameter is 1223 yards; and one which magnifies a thousand times, will enable us to perceive any enlightened object on her surface whose dimensions are only 122 yards, which does not much exceed the dimensions of some of our public edifices.

Illustration. For instance, the Capitol at Washington, or St. Paul's Cathedral. Professor Fraunhofer of Munich, recently announced that he had discovered a lunar edifice, resembling a *fortification*, together with *several lines of road.* The celebrated astronomer Schroeter, conjectures the existence of a great city on the east side of the Moon, a little north of her equator, an extensive canal in another place, and fields of vegetation in another.

CXLIX. It may be demonstrated from the laws of optics, that there exists no physical impossibility to the construction of instruments sufficiently powerful to settle the question of the Moon being inhabited. The difficulty which prevented the great telescope of Herschel from revealing this secret, was not so much the want of *power in the lens*, as of *light in the tube*, to render objects distinct under such an expansion of the visual rays.

SOLAR AND LUNAR ECLIPSES.

CL. Of all the phenomena of the heavens, there are none which engage the attention of mankind more than eclipses of the Sun and Moon; and to those who are unacquainted with astronomy, nothing appears more wonderful than the accuracy with which they can be predicted. In the early ages of antiquity they were regarded as alarming deviations from the established laws of nature, presaging great public calamities and other tokens of the Divine displeasure.

An eclipse of the Sun takes place when the dark body of the Moon, passing directly between the Earth and the

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CXLVIII. How small a spot on the Moon's surface can be seen by a telescope which magnifies 100 times? How small an enlightened object can be seen by one which magnifies 1000 times? Mention any public edifices which are of nearly the same dimensions. CXLIX. Why may not a telescope be made by which we can determine the question of the Moon being inhabited? CL. How were eclipses regarded in the early ages of antiquity? What causes eclipses of the Sun

Sun, intercepts his light. This can happen only at the instant of *new* Moon, or when the Moon is in conjunction; for it is only then that she passes between us and the Sun.

An eclipse of the Moon takes place when the dark body of the Earth, coming between her and the Sun, intercepts his light, and throws a shadow on the Moon. This can happen only at the time of *full* Moon, or when the Moon is in opposition; for it is only then that the Earth is between her and the Sun.

As every planet belonging to the solar system, both primary and secondary, derives its light from the Sun, it must cast a shadow towards that part of the heavens which is opposite to the Sun. This shadow is of course nothing but a privation of light in the space hid from the Sun by the opaque body, and will always be proportioned to the magnitude of the Sun and planet.

If the Sun and planet were both of the same magnitude, the form of the shadow cast by the planet, would be that of a cylinder, and of the same diameter as the Sun or planet.

CLI. An eclipse of a heavenly body is caused by another heavenly body passing over its disk and obscuring its surface.

CLII. The Moon is eclipsed, **when she is received in** the Earth's shadow, as seen in fig. 17, page 232, where is represented the Moon passing through the Earth's shadow. It has been ascertained by careful astronomical calculation, that when the Sun is at his greatest distance from the Earth, and the Moon at her least distance, the Moon's shadow not only reaches the Earth, but nearly 20,000 miles farther: but on the contrary, when the Sun is nearest, and the Moon farthest from the Earth, the Moon's shadow extends only 220,000 miles, terminating

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What causes eclipses of the Moon? In what direction does every planet of the solar system cast a shadow? What is this shadow, and to what is it proportional? If the Sun and planet were both of the same magnitude, what would be the form o. the shadow, and its diameter? CLI. Define an eclipse. CLII. What occasions an eclipse of the Moon?

20,000 miles before it reaches our Earth. No eclipse either of the Sun or Moon can happen, unless the Sun, Moon, and Earth, are in, or nearly in a straight line.

CLIII. If the orbit of the Moon were exactly in the same plane as that of the Earth, there would be an eclipse of the Sun every time that the Sun and Moon happened to be on the same side of the Earth. This effect is prevented, by the angle which is made by the plane of the Moon's orbit, with that of the Earth's orbit, which is 5° 30′. Were it not for the angle above named, there would be an eclipse of the Sun every lunar month.

CLIV. The *nodes* of the Moon are those points in her orbit, where the plane of her orbit, cuts the plane of the Earth's orbit; or in other words, it is those places where the Moon's and the Earth's orbit cross each other.

CLV. These two nodes are denominated the *ascending* and *descending* nodes, the reason of which will be obvious if we suppose for the sake of illustration, the plane of the Earth's orbit to be horizontal, and that of the Moon's orbit inclined but crossing that of the Earth; now one half of the Moon's orbit would then be below that of the Earth, and the other half above it. Accordingly when the Moon crosses the Earth's orbit to go below it she is said to pass through her *descending* node: when on the contrary, she is rising into the upper portion of her orbit, she is said to pass her *ascending* node.

CLVI. The Moon like the other heavenly bodies, has an elliptical orbit as may be seen by inspecting fig. 14, page 215, where the Earth is represented in an elliptical orbit, and then seen within it near the centre, where the Moon must be nearer the Earth in some parts of her orbit than in others. When she is in the nearest part, she

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In eclipses of the Moon, what planet is between the Sun and Moon? In eclipses of the Sun, what planet is between the Sun and Earth? CLIII. Why is there not an eclipse of the Sun at every conjunction of the Sun and Moon? How many degrees is the Moon's orbit inclined to that of the Earth? CLIV. What are the nodes of the Moon? CLV. What is meant by the ascending and descending nodes of the Moon? CLVI. What is is the Moon's apogee, and what her perigee?

is said to be in *perigee*, but when in the farthest part, in *apogee*.

CLVII. The Moon must be at or near her nodes during an eclipse, because the Sun, Moon, and Earth never come in the same line except in this position.

CLVIII. The reason eclipses do not happen more frequently, and more regularly is, because the Moon in passing her nodes is not in conjunction with the Sun, more than twice or thrice in a year.

CLIX. It is found both by calculation and by observation, that the average number of eclipses of Sun and Moon together annually is four. Seven is the most, and two the least that can occur in a year.

CLX. To have an eclipse of the Sun, the Moon must be within $16\frac{1}{2}^{\circ}$ of her node, which must also be at the time of new Moon; and to have an eclipse of the Moon, she must be within 12° degrees of her nodes, and this at the time of full Moon. Now as the former condition of things takes place much more frequently than the latter, there must necessarily be more solar than lunar eclipses in any given term of years.

CLXI. Though solar eclipses occur in reality more frequently than lunar, yet an individual in any given place on the Earth, will see a greater number of the latter in a given time than of the former; the cause of which seems to be this: the lunar eclipse is produced by the shadow of the Earth on the Moon, and is visible to the whole hemisphere of the Earth, that is towards the Moon; therefore one half of the inhabitants of our Earth would see an eclipse of the Moon if the Earth were at rest on her axis, but as she is constantly rotating more than half the

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CLVII. Why must the Moon be at or near one of her nodes, to occasion an eclipse? CLVIII. Why do not eclipses happen often, and at regular periods? CLIX. What is the greatest, and what the least number of eclipses, that can happen in a year? CLX. Why will there be more solar than lunar eclipses, in the course of years? CLXI. Why will more lunar than solar eclipses be visible at one place?

inhabitants must see every lunar eclipse. The solar eclipse is produced by the shadow of the Moon, falling on the Earth, and can never cover a space of more than 5,000 miles in diameter and a total eclipse, only 175 miles in diameter. The consequence is that the inhabitants of any given place on the Earth, will see at least half of all the lunar eclipses, while the same individuals may not see more than one fourth of the solar eclipses.

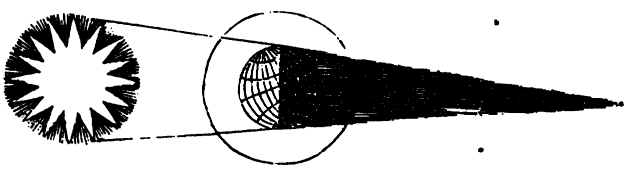
CLXII. *Lunar Eclipses* as already described arise from the passage of the Moon into the shadow of the Earth, so the Sun's rays are prevented from reaching the Moon and she is said to be eclipsed.

CLXIII. The eclipse is *partial* when the shadow covers but a part of her disk, and *total* when it covers the whole.

Illustration. Fig. 17 below, represents a total eclipse; on the left of the figure is the Sun, to the right of which is the Earth, and the Moon in her orbit passing through the Earth's shadow which comes to a conical point at the extreme right of the figure. It will be quite evident from inspection of the figure, that the Moon thus obscured, would be visible to all spectators on that hemisphere of the Earth, that is turned towards the Moon, such eclipses only occurring at full Moon, as is evident from its position with regard to the Earth and Sun.

Fig. 17.

Eclipse of the Moon.



CLXIV. *Solar Eclipses* take place when the Moon comes between the Earth and the Sun, and the Moon's shadow is received on the Earth.

CLXII. Define a lunar eclipse. CLXIII. Why is the same eclipse total at one place, and only partial at another? CLXIV. Define a solar eclipse.

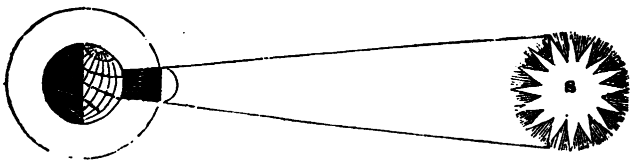
CLXV. Solar eclipses are *total*, *partial*, *central* and *annular*. They are *total*, when the Sun's disk is entirely obscured, and *partial* when it is partly illuminated, and partly obscured. They are *central*, when the centres of the Sun, Moon, and Earth, are in the same straight line.

CLXVI. A total eclipse is confined to an area not more than 200 miles in diameter while a partial eclipse may extend over 4,000 miles.

Illustration. The following cut is introduced, to show how small an area on the Earth is totally eclipsed in a solar eclipse. Here S, fig. 18 represents the Sun, while on the left of the figure, is the Earth and the Moon obstructing the Sun's rays and casting a shadow on a small portion of the Earth.

Fig. 18.

Eclipse of the Sun.



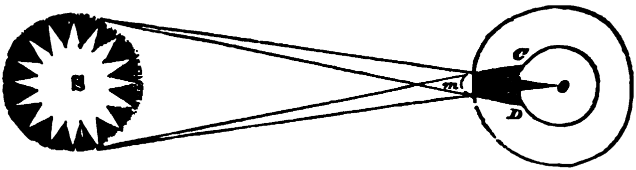
CLXVII. A central eclipse is annular, when the Moon is at so great a distance from the Earth, that its area is not large enough to conceal the entire disk of the Sun, and there will be seen surrounding her dark body, a ring of dazzling light.

Illustration. This is seen in the following diagram, fig. 19, where S represents the Sun, *m* the Moon, *o* the apex of the conical shadow, in any part of which the eclipse will be total. This conical shadow *m o*, when the Sun is at his greatest, and the Moon at her least distance from the Earth, terminates 20,000 miles before it reaches the Earth; so also when the Sun and Moon are at their mean distances from the Earth, their shadow terminates a little before it reaches the Earth, and if any person stand a little beyond the point *o*, he will see the luminous ring bordering the Sun's disk, while the central portions are obscured by the Moon which intervenes.

The partial shadows D and C, are called the *penumbra*, while the dark shadow *m o*, is call the *umbra*.

CLXV. How many varieties of solar eclipses? Define *total*, *partial*, and *central*. CLXVI. What spaces are covered by total and by partial eclipses? CLXVII. How does a central eclipse become annular? Give the illustration by the diagram.

Fig. 19.



It will be seen by inspection of fig. 19, that an eclipse will be total only to those within the umbra, and partial to all without it; it will be central to all those in a line corresponding with *m o*, or with a line passing through the centre of the Sun S, the centre of the Moon *m*, and extends through *o*; it will be annular only to those behind *o*, and in the direct line S *m o*.

CLXVIII. It will be remembered that the Earth would appear to a spectator in the Moon, much the same as the Moon appears to us, but larger. If therefore we suffer a solar eclipse, the Earth will appear to the Moon, as the Moon does to us in a lunar eclipse, but the shadow will be confined to a small space, and will appear like a dark spot. If we have a lunar eclipse, a spectator in the Moon, would have a solar eclipse, caused by the Earth coming between him and the Sun.

THE TIDES.

CLXIX. The oceans and most seas are observed to be incessantly agitated for certain periods of time, first from the east towards the west, and then again from the west towards the east. In this motion, which lasts about six hours, the sea gradually swells; so that entering the mouths of rivers, it drives back the waters toward their source. After a conditional flow of six hours, the seas seem to rest for about a quarter of an hour; they then begin to ebb, or retire back again from west to east for

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Are annular eclipses ever total in any part of the Earth? In annular eclipses what part of the Moon's shadow reaches the Earth? CLXVIII. What is said concerning eclipses of the Earth, as seen from the Moon? CLXIX. Define the tides.

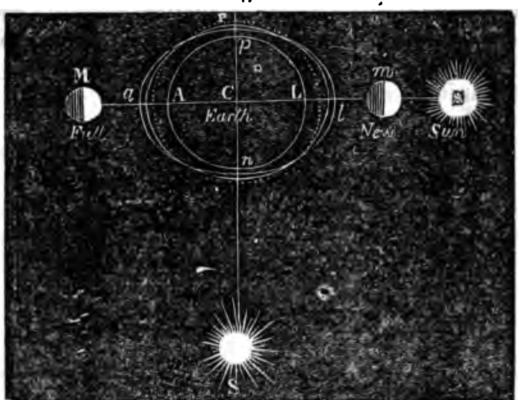
six hours more; and the rivers again resume their natural courses. Then after a seeming pause of a quarter of an hour, the seas again begin to flow as before. This regular and alternate motion of the sea constitutes *the tides*, of which there are two in something less than twenty-five hours.

Observation. The ancients considered the ebbing and flowing of the tides as one of the greatest mysteries in nature, and were utterly at a loss to account for them. Galileo and Descartes, and particularly Kepler, made some successful advances toward ascertaining the cause; but Sir Isaac Newton was the first who clearly showed what were the chief agents in producing these motions.

CLXX. Tides are caused by the attraction of the Sun and Moon, but mostly by that of the Moon, the tendency of which is to draw the waters of the ocean on that side next the Moon away from the centre of the Earth; again while the Moon attracts the centre of the Earth, more than the water, in the hemisphere opposite to her, the Earth is drawn away from those waters causing them to be elevated, producing a tide simultaneous with the first.

Illustration. Let *Ap Ln*, fig. 20, be the Earth, and C its centre; let the

Fig. 20.



Give the substance of the observation. CLXX. What is the cause of the tides? How does the attraction of the Sun and Moon produce tides upon both sides of the Earth at the same time?

dotted circle P N represent a mass of water covering the surface of the Earth; let M *m*, be the Moon; S *s*, the Sun in different situations. Because the power of gravity diminishes as the squares of the distances increase, the waters on the side of the Earth A are more attracted by the Moon at M, than the central parts of the Earth C, and the central parts are more attracted than the waters on the opposite side of the Earth at L; consequently the waters on the side L will be attracted less than the centre, or will recede from the centre. Therefore, while the Moon is at M, the waters will rise towards *a* and *l* on the opposite sides of the Earth A L; while, by the oblique attraction of the Moon, the waters at P and N will be depressed.

Observation. That the Moon, says Sir John Herschel, should by her attraction, heap up the waters of the ocean under her, seems to most persons very natural; but that the same cause should at the same time, heap them up on the opposite side, seems, to many, palpably absurd. Yet nothing is more true, no' 'ndeed more evident, when we consider that it is not by her *whole* attraction, but by the differences of her attractions at the opposite surfaces and at the centre, that the waters are raised.

That the tides are dependant upon some known and determinate laws, is evident from the exact time of high water being previously given in every ephemeris, and in many of the common almanacs.

The Moon comes every day later to the meridian than on the day preceding, and her exact time is known by calculation; and the tides in any and every place, will be found to follow the same rule; happening exactly so much later every day as the Moon comes later to the meridian. From this exact conformity to the motions of the Moon, we are induced to look to her as the cause; and to infer that those phenomena are occasioned principally by the Moon's attraction.

CLXXI. If the Earth were at rest, and there were no attractive influence from either the Sun or Moon, it is obvious from the principles of gravitation, that the waters in the ocean would be truly spherical; (as represented by fig. 21) but daily observation proves that they are in a state of continual agitation.

Fig. 21.

Fig. 22.

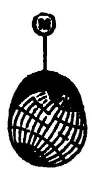
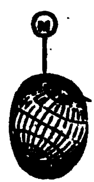


Fig. 23.

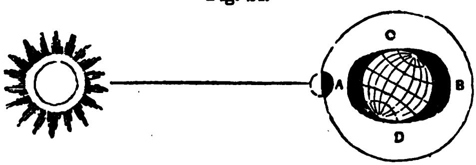


What is Sir John Herschel's remark upon this theory? How is it known that the tides are governed by any ascertained law? What coincidence is observed between the meridian passage of the Moon, and the time of high water? What conclusion may we derive from this coincidence? CLXXI. If the Earth were at rest, and under no influence from the attraction of the Sun or Moon, what shape would the waters assume?

CLXXII. If the Earth and Moon were without motion, and the Earth covered all over with water, the attraction of the Moon would raise it up in a heap, in that part of the ocean to which the Moon is vertical, as in figure 22, and there it would, probably, always continue; but by the rotation of the Earth upon its axis, each part of its surface to which the Moon is vertical is presented to the action of the Moon; wherefore, as the quantity of water on the whole Earth remains the same, when the waters are elevated on the side of the Earth under the Moon, and on the opposite side also, it is evident they must recede from the intermediate points, and thus the attraction of the Moon produce *high water* at two opposite places, and *low water* at two opposite places on the Earth, at the same time, as represented by figure 23.

Illustration. This is evident from the following figure. The waters cannot rise in one place, without falling in another; and therefore they must fall as low in the horizon at C and D, as they rise in the zenith and nadir at A and B.

Fig. 24.



CLXXIII. The length of the lunar day, that is, of the interval from one meridian passage of the Moon to another, being at a mean rate, 24 hours, 48 minutes and 44 seconds; the interval between the flux and the reflux of the sea is not at a mean rate, precisely six hours, but *twelve minutes and eleven seconds* more, so that the time of high water does not happen at the same hour, but is about 49 minutes later every day.

CLXXII. Suppose the attractive power of the Moon upon the Earth to be as it is, and neither the Earth or Moon to have any motion, what would be the result? How would this condition of things be affected by the Earth's rotation? CLXXIII. What is the average interval between the flux and reflux of the sea? What is the length of a lunar day, and of the interval of the flux and reflux of the sea?

CLXXIV. The Earth revolves on its axis in about 24 hours; if the Moon, therefore, were stationary, the same part of our globe would return beneath it, and there would be two tides every 24 hours; but while the Earth is turning once upon its axis, the Moon has gone forward 13° in her orbit—which takes forty-nine minutes more before the same meridian is brought again directly under the Moon. And hence every succeeding day the time of high water will be forty-nine minutes later than the preceding.

Illustration. Suppose at any place it be high water at 3 o'clock in the afternoon, upon the day of new Moon; the following day it will be high water about 49 minutes after 3; the day after, about 38 minutes after 4; and so on, till the next new Moon. The exact daily mean retardation of the tides is thus determined:—

The mean motion of the Moon in a solar day, is 13°.17639639
The mean motion of the Sun in a solar day, is 0 .98564722

Now, as 15° is to 60 minutes, so is 12°.19074917 to 48′44″.

CLXXV. The tides, though constant, are not equal; they are greatest when the Moon is in conjunction with, or in opposition to the Sun; and least when in quadrature. The former are called *Spring Tides;* the latter, *Neap Tides.* The spring tides are highest, when the Sun and Moon are near the equator, and the Moon at her least distance from the Earth. The neap tides are lowest, when the Moon in her first and second quarters is at her greatest distance from the Earth. The general theory of the tides is this: when the Moon is nearest the Earth, her attraction is strongest, and the tides are the highest: when she is farthest from the Earth, her attraction is least, and the tides are the lowest.

CLXXVI. From the above theory, it might be supposed that the tides would be the highest when the Moon was on the meridian. But it is found that in open seas,

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CLXXIV. How is this daily retardation of the tides accounted for? Give the illustration. CLXXV. Are the tides uniformly high? What are these extreme tides called? When are the spring tides highest, and the neap tides lowest? What is the general theory upon this subject? CLXXVI. Does it necessarily result from this theory, that the tide is highest when the Moon is on the meridian?

where the water flows freely, the Moon has generally *passed the north or south meridian about three hours, when it is high water.* The reason is, that the force by which the Moon raises the tide *continues to act,* and consequently the waters continue to rise, after she has passed the meridian.

CLXXVII. For the same reason, the highest tides, which are produced by the conjunction and opposition of the Sun and Moon, or when the Sun and Moon are on opposite sides of the Earth, do not happen on the days of the full and change; neither do the lowest tides happen on the days of their quadrature. But the greatest *spring tides* commonly happen *three days after* the new and full Moons; and the least *neap tides three days after* the first and third quarters.

Illustration. The Sun and Moon, by reason of the elliptical form of their orbits, are alternately nearer to and farther from the Earth, than their mean distances. In consequence of this, the efficacy of the Sun will fluctuate between the extremes 19 and 21, taking 20 for its mean value, and between 43 and 59 for that of the Moon. Taking into account this cause of difference, the highest spring tide will be to the lowest neap as 59+21 is to 43—19, or as 80 to 24, or 10 to 3. The relative *mean* influence is as 51 to 20, or as 5 to 2, *nearly.—Herschel's Astr.* p. 339.

CLXXVIII. Though the tides in *open seas,* are at the highest about *three hours* after the Moon has passed the meridian, yet the waters in their passage through shoals and channels, and by striking against capes and headlands, are so retarded that, the tides happen at all distances of the Moon from the meridian, and consequently, at all hours of the lunar day.

CLXXIX. In small collections of water, the Moon acts at the same time on every part; diminishing the gravity of the whole mass. On this account there are no sensible tides in lakes, they being generally so small that when the Moon is vertical, it attracts every part alike;

What reason is assigned for this? CLXXVII. What similar fact is accounted for upon the same principle? What is the comparative force of the solar and lunar attraction upon the Earth? CLXXVIII. To what is owing the great difference in the time of high water at places lying under the same meridian? CLXXIX. Why are there no tides upon lakes, and small collections of water?

and by rendering all the waters equally light, no part of them can be raised higher than another. The Mediterranean and Baltic seas have very small elevations, partly for this reason, and partly because the inlets by which they communicate with the ocean are so narrow, that they cannot in so short a time, either receive or discharge enough, sensibly to raise or sink their surfaces.

CLXXX. Of all the causes of difference in the height of tides at different places, by far the greatest is local situation. In wide-mouthed rivers, opening in the direction of the stream of the tides, and whose channels are growing gradually narrower, the water is accumulated by the contracting banks, until in some instances it rises to the height of 20, 30, and even 50 feet.

CLXXXI. Air being lighter than water, and the surface of the atmosphere being nearer to the Moon than the surface of the sea, it cannot be doubted but that the Moon raises much higher tides in the atmosphere than in the sea. According to Sir John Herschel these tides are, by very delicate observations, rendered not only sensible, but *measurable*.

Observation. Upon the supposition that the waters on the surface of the Moon are of the same specific gravity as our own, we might easily determine the height to which the Earth would raise a lunar tide, by the known principle, that the attraction of one of these bodies on the other's surface is *directly* as its quantity of matter, and *inversely* as its diameter. By making the calculation, we shall find the attractive power of the Earth upon the Moon to be 21.777 times greater than that of the Moon upon the Earth.

SOLAR OR SIDEREAL TIME

CLXXXII. By a solar or natural day we mean the time taken by the sun to go from any meridian until it come to the same meridian again, or from noon of one day till noon of the next, which is about twenty-four

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CLXXX. To what cause, more than to all others, is the different height of tides owing? Explain this. CLXXXI. Is it probable that the Moon exerts any influence of attraction on the atmosphere? Why is it probable? Are the atmospheric tides sufficiently sensible to be appreciated? How much greater is the attractive power of the Earth upon the Moon, than that of the Moon upon the Earth? CLXXXII. Define solar and sidereal time.

hours, but varies, sometimes being a little less and at others a little more.

By a sidereal day we mean the time that elapses between the passage of any given meridian, as of New York, from any fixed star, as Sirius, and the return of the same meridian to the same star which is 23 hours, 56 minutes, and 4 seconds. The difference therefore between a solar and sidereal day is 3 minutes and 56 seconds, which in a solar year amounts to 23 hours 57 minutes and 20 seconds, being 2 minutes and 40 seconds short of a solar day; therefore a solar year is 365 days and a fraction, while a sidereal year is nearly 366 days or revolutions of the earth on its axis.

Illustration. The difference between solar and sidereal time is caused by the movement of the Earth in its orbit; this may be illustrated by the hands on the dial of a watch; suppose the hour 12 to represent any fixed star, and the hour and minute-hands (the former representing the Sun the latter the Earth,) to be at 12. The minute-hand or Earth will make a complete revolution and arrive at 12 the fixed star completing a sidereal day, but in the mean time the Sun or hour-hand will have moved on to 1; the solar day therefore will not be completed until the minute hand reach 1; so in each revolution the solar will be longer than the sidereal day. It should be stated that the point of the minute-hand while it represents the motion of the Earth in its orbit also represents some given meridian of the Earth.

CLXXXIII. Had the Earth only a diurnal motion a solar and sidereal day would exactly correspond—because in that case using the illustration of CLXXXII. the Sun or hour-hand would remain at 12 on the return of the Earth or minute-hand to the same meridian.

Illustration. This subject may be illustrated still further by the diagram Fig. 25. Let S be the Sun and A, B, C, different positions of the Earth in its orbit, a portion of which is represented by the curved line. Let the Sun S be on a given meridian *e* while the Earth is at A, then a ray from the Sun towards the centre of the Earth coincides with the light line *e*; but while the Earth moves on in her orbit from A to B or from west to east, she completes her revolution with regard to a fixed star when she arrives at *e* in position B, but she will not have completed her solar day until she passes from *e* to *o*, and in position C the sidereal will have gained still more upon the solar day. The 3 minutes and 56 seconds of gain, each day in a solar over

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How can we account for this difference? CLXXXIII. Had the Earth only a diurnal revolution, would the siderial and solar time agree? Why does not the Earth turn the same meridian to the Sun at the same time every day?

the siderial day corresponds with about 1-365th part of a circle, or a little less than a degree.

Fig. 25.

CLXXXIV. Thus, it is obvious, that the Earth must complete one revolution, and a portion of a second revolution, equal to the space she has advanced in her orbit, in order to bring the same meridian back again to the Sun. This small portion of a second revolution amounts daily to the 365th part of her circumference, and therefore, at the end of the year, to one entire rotation, and hence in 365 days, the Earth actually turns on her axis 366 times. Thus, as one complete rotation forms a siderial day, there must, in the year, be one siderial more than there are solar days, one rotation of the Earth, with respect to the Sun, being lost by the Earth's yearly revolution. The same loss of a day happens to a traveller, who, in passing round the Earth toward the west, reckons his time by the rising and setting of the Sun. If he passes round toward the east, he will gain a day for the same reason.

EQUATION OF TIME.

CLXXXV. As the motion of the Earth about its axis

Show by fig. 25, how siderial differs from solar time. CLXXXIV. How many times does the Earth turn on her axis in a year? Why does she turn more times than there are days in the year? CLXXXV. Why are the solar days sometimes greater and sometimes less than 24 hours

is perfectly uniform, the siderial days, as we have already seen, are exactly of the same length in all parts of the year. But as the orbit of the Earth, or the apparent path of the Sun is inclined to the Earth's axis, and as the Earth moves with different velocities in different parts of its orbit, the solar or natural days, are sometimes greater and sometimes less than 24 hours, as shown by an accurate clock. The consequence is, that a true sundial or noon-mark, and a true timepiece, agree with each other only a few times in a year.

CLXXXVI. The difference between the sundial and clock, thus shown, is called the *equation of time.*

CLXXXVII. The difference between the Sun and a well-regulated clock, thus arises from two causes, the inclination of the Earth's axis to the ecliptic, and the elliptical form of the Earth's orbit.

That the Earth moves in an ellipse, and that its motion is more rapid sometimes than at others, as well as that the Earth's axis is inclined to the ecliptic, have already been explained and illustrated. It remains, therefore, to show how these two combined causes, the elliptical form of the orbit, and the inclination of the axis, produce the disagreement between the Sun and clock. In this explanation, we must consider the Sun as moving around the ecliptic, while the Earth revolves on her axis

CLXXXVIII. *Equal* or *mean* time, is that which is reckoned by a clock, supposed to indicate exactly 24 hours, from 12 o'clock on one day to 12 o'clock on the next day. *Apparent* time, is that which is measured by the apparent motion of the Sun in the heavens, as indicated by a meridian line, or sundial.

Were the Earth's orbit a perfect circle, and her axis perpendicular to the plane of this orbit, the days would be of

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CLXXXVI. What is the difference between the time of a sun-dial and a clock called? CLXXXVII. What are the causes of the difference between the Sun and clock? In explaining equation of time, what motion is considered as belonging to the Sun, and what motion to the Earth? CLXXXVIII. What is equal, or mean time, and what is apparent time?

uniform length, and there would be no difference between the clock and the Sun; both would indicate 12 o'clock at the same time, on every day in the year. But on account of the inclination of the Earth's axis to the ecliptic, unequal portions of the Sun's apparent path through the heavens will pass any meridian in equal times.

PRECESSION OF THE EQUINOXES.

CLXXXIX. A *tropical* year is the time it takes the Sun to pass from one equinox or tropic, to the same tropic or equinox again.

CXC. A *siderial* year is the time it takes the Sun to perform his apparent annual revolution, from a fixed star to the same fixed star again.

CXCI. Now it has been found that these two revolutions are not completed in exactly the same time, but that it takes the Sun about 20 minutes longer to complete his apparent revolution in respect to the *star*, than it does in respect to the *equinox*, and hence the siderial year is about 20 minutes longer than the tropical year. The revolution of the Earth from equinox to equinox, again, therefore *precedes* its complete revolution in the ecliptic by about 20 minutes, for the absolute revolution of the Earth is measured by its return to the fixed star, and not by the return of the Sun to the same equinoctial point.

CXCII. This apparent falling back of the equinoctial point, so as to make the time when it meets the Sun *precede* the time when the Earth makes its complete revolution in respect to the star, is called the *precession of the equinoxes*.

CXCIII. The distance which the Sun thus gains upon the fixed star, or the difference between the Sun and star, when the Sun has arrived at the equinoctial point, amounts

CLXXXIX. What is a tropical year? CXC. What is a siderial year? CXCI. What is the difference in the time which it takes the Sun to complete his revolution in respect to a star, and in respect to the equinox? CXCII. Explain what is meant by the precession of the equinoxes. CXCIII. How many seconds of a degree does the equinox recede every year, when the Sun's place is compared with a star?

to 50 seconds of a degree, thus making the equinoctial point recede 50 seconds of a degree, (when measured by the signs of the zodiac,) westward every year, contrary to the Sun's annual progressive motion in the ecliptic.

CXCIV. The precession of the equinoxes, being 50 seconds of a degree every year, contrary to the Sun's apparent motion, or about 20 minutes in time, short of the point where the Sun and equinoxes coincided the year before; it follows, that the fixed stars, or those in the sign of the zodiac, move forward every year 50 seconds, with respect to the equinoxes.

CXCV. In consequence of this precession, in 2160 years, those stars which now appear in the beginning of the sign Aries, for instance, will then appear in the beginning of Taurus, having moved forward one whole sign, or 30°, with respect to the equinoxes, or the equinoxes having gone backward 30°, with respect to the stars. In 12,960 years or 6 times 2160 years, therefore, the stars will appear to have moved forward one half of the whole circle of the heavens, so that those which now appear in the first degree of the sign Aries, will then be in the opposite point of the zodiac, and therefore, in the first degree of Libra. And in 12,960 years more, because the equinoxes will have fallen back the other half of the circle, the stars will appear to have gone forward from Libra to Aries, thus completing the whole circle of the zodiac.

CXCVI. Thus in about 26,000 years the equinox will have gone backward a whole revolution around the axis of the ecliptic, and the stars will appear to have gone forward the whole circle of the zodiac.

CXCVII. The discovery of the precession of the equinoxes has thrown much light on ancient astronomy and chronology, by showing an agreement between ancient

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CXCIV. How many minutes in time, is the precession of the equinoxes per year? CXCV. What effect does this precession produce on the fixed stars? How many years is a star in going forward one degree, in respect to the equinoxes? In how many years will the stars appear to have passed half around the heavens? CXCVI. In what period will the Earth appear to have gone backward one whole revolution? CXCVII. In what respect is the precession of the equinoxes an important subject?

and modern observations, concerning the places of the signs of the zodiac, not to be reconciled in any other manner.

CXCVIII. The cause of the precession of the equinoxes is the action of the Sun and Moon on the protuberant matter about the Earth's equator, that matter which causes the equatorial diameter to be 34 miles longer than the polar diameter. It is this protuberant matter at the equator of the Earth that causes a movement of the Earth about the axis of the ecliptic which is the precession of the equinoxes; or the precession of the equinoxes is a retrograde motion of the equinoctial points from the action of the Sun and Moon, on the protuberent matter about the Earth's equator.

MARS

CXCIX. Mars is the first of the exterior planets, its orbit lying immediately *beyond* that of the Earth, while those of Mercury and Venus are *within.*

CC. Mars appears to the naked eye, of a fine ruddy complexion; resembling, in colour, and apparent magnitude, the star Antares, or Aldebaran, near which it frequently passes. It exhibits its greatest brilliancy about the time that it rises when the Sun sets, and sets when the Sun rises; because it is then nearest the Earth. It is least brilliant when it rises and sets with the Sun; for then it is five times farther removed from us than in the former case.

CCI. Its distance from the Earth at its nearest approach is about 50,000,000 of miles. Its greatest distance from us is about 240,000,000 of miles. In the former case, it appears nearly 25 times larger than in the latter. When it rises before the Sun, it is our morning star; when it sets after the Sun, it is our evening star.

CXCVIII. What is the cause of the precession of the equinoxes? CXCIX. What is the position of Mars in the solar system? CC. Describe its appearance to the naked eye? When does it exhibit its greatest brilliancy? Why is it most brilliant at this time? CCI. What are its least and greatest distances from us? How much larger does it appear in the former case, than in the latter?

CCII. Mars is sometimes seen in opposition to the Sun, and sometimes in superior conjunction with him; sometimes gibbous, but never horned. In *inferior* conjunction, it is never seen to pass over the Sun's disk, like Mercury and Venus. This proves not only that its orbit is *exterior* to the Earth's orbit, but that it is an opaque body, shining only by the reflection of the Sun.

CCIII. The motion of Mars through the constellations of the zodiac, is but little more than *half* as great as that of the Earth; it being generally about 57 days in passing over one sign, which is at the rate of a little more than half a degree each day. Thus if we know what constellation Mars enters to-day, we may conclude that two months hence it will be in the next constellation; four months hence, in the next; six months, in the next, and so on.

CCIV. Mars performs his revolution around the Sun in 1 year and $10\frac{1}{2}$ months, at the distance of 145,000,000 of miles; moving in its orbit at the mean rate of 55,000 miles an hour. Its diurnal rotation on its axis is performed in 24 hours, 39 minutes, and $21\frac{1}{3}$ seconds; which makes its day about 44 minutes longer than ours.

CCV. Its form is that of an oblate spheroid, whose polar diameter is to its equatorial, as 15 is to 16, nearly. Its mean diameter is 4222 miles. Its bulk, therefore, is 7 times less than that of the Earth; and being 50,000,000 of miles farther from the Sun, it receives from him only half as much light and heat.

CCVI. The inclination of its axis to the plane of its

CCII. What moon-like phases has Mars? What does the fact that it never assumes the crescent form at its inferior conjunction prove, in regard to its situation? How do we know it to be opaque? CCIII. What is the rate of its motion through the constellations of the zodiac, compared with that of the Earth? How long is it in passing over one sign? At what rate per day is this? How, then, if we know in what constellation it is at any one time, may we determine in what constellation it will be at any subsequent time? CCIV. In what time does it perform its revolution around the Sun? What is its distance from the Sun? What is the mean rate of its motion in its orbit per hour? In what time does it perform its revolution on its axis? What, then, is the length of its day, compared with that of the Earth? CCV. What are its form and dimensions? What, then, is its bulk, compared with the Earth's, and how much less light and heat does it receive from the Sun? CCVI. What is the inclination of its axis to the plane of its orbit?

orbit, is about $28\frac{2}{3}°$. Consequently, its seasons must be very similar to those of the Earth. Indeed, the analogy between Mars and the Earth is greater than the analogy between the Earth and any other planet of the solar system. Their diurnal motion, and of course the length of their days and nights are nearly the same; the obliquity of their ecliptics, on which the seasons depend, are not very different; and, of all the superior planets, the distance of Mars from the Sun is by far the nearest to that of the Earth; nor is the length of its year greatly different from ours, when compared with the years of Jupiter, Saturn, and Herschel.

CCVII. To a spectator on this planet, the Earth will appear alternately, as a morning and evening star; and will exhibit all the phases of the Moon, just as Mercury and Venus do to us; and sometimes, like them, will appear to pass over the Sun's disk like a dark round spot. Our Moon will never appear more than *a quarter of a degree* from the Earth, although her distance from it is 240,000 miles. If Mars be attended by a satellite, it is too small to be seen by the most powerful telescopes.

CCVIII. The telescopic phenomena of Mars afford peculiar interest to astronomers. They behold its disk diversified with numerous irregular and variable spots, and ornamented with zones and belts of varying brilliance, that form, and disappear, by turns. Zones of intense brightness are to be seen in its polar regions, subject, however, to gradual changes. That of the southern pole is much the most brilliant. Dr. Herschel supposes that they are produced by the reflection of the Sun's light from the frozen regions, and that the melting of these masses of polar ice is the cause of the variation in their magnitude and appearance.

How are its seasons, compared with those of the Earth? In what particulars is there a greater analogy between Mars and the Earth, than between the Earth and any other planet in the solar system? CCVII. What must be the appearance of the Earth to a spectator at Mars? What is the greatest distance from the Earth at which our Moon will appear to him to be? CCVIII. What are the telescopic phenomena of Mars? How does Dr. Herschel account for them?

Observation 1. He was the more confirmed in these opinions by observing, that after the exposure of the luminous zone about the north pole to a summer of eight months, it was considerably *decreased*, while that on the south pole, which had been in total darkness during eight months, had considerably *increased*.

2. He observed, farther, that when this spot was most luminous, the disk of Mars did not appear exactly *round*, and that the bright part of its southern limb seemed to be swollen or arched out beyond the proper curve.

Fig. 26.
Telescopic Appearances of Mars.

CCIX. The extraordinary height and density of the atmosphere of Mars, are supposed to be the cause of the remarkable redness of its light.

THE ASTEROIDS, OR TELESCOPIC PLANETS.

CCX. Ascending higher in the solar system, we find, between the orbits of Mars and Jupiter, a cluster of four small planets, which present a variety of anomalies that distinguish them from all the older planets of the system. Their names are *Vesta*, *Juno*, *Ceres*, and *Pallas*. They were all discovered about the beginning of the present century.

CCXI. The dates of their discovery, and the names of their discoverers, are as follows:—

Ceres, January 1, 1801, by M. Piazzi, of Palermo.
Pallas, March 28, 1802, by M. Olbers, of Bremen.
Juno, September 1, 1804, by M. Harding, of Bremen.
Vesta, March 29, 1807, by M. Olbers, of Bremen.

CCIX. How may the remarkable redness of the light of Mars be accounted for? CCX. What new planets have been discovered within the present century, and where are they situated? CCXI. What are the dates of their discovery, and the names of their discoverers?

CCXII. The scientific Bode entertained the opinion, that the planetary distances, above Mercury, formed a geometrical series, each exterior orbit being double the distance of its next interior one, from the Sun; a fact which obtains with remarkable exactness between Jupiter, Saturn, and Herschel. But this law seemed to be interrupted between Mars and Jupiter. Hence he inferred, that there was a planet wanting in that interval; which is now happily supplied by the discovery of the four *star-form* planets, occupying the very space where the unexplained vacancy presented a strong objection to his theory.

CCXIII. These bodies are *much smaller* in size than the older planets—they all revolve *at nearly the same distances* from the Sun, and perform their revolutions in *nearly the same periods*,—their orbits are much *more eccentric*, and have a *much greater inclination* to the ecliptic,—and what is altogether singular, except in the case of comets—*all cross each other;* so that there is even a *possibility* that two of these bodies, may, sometime, in the course of their revolutions, come into collision.

CCXIV. The orbit of Vesta is so eccentric, that she is sometimes farther from the Sun than either Ceres, Pallas, or Juno, although her mean distance is many millions of miles less than theirs. The orbit of Vesta crosses the orbits of all the other three, in two opposite points.

CCXV. From these and other circumstances, many eminent astronomers are of opinion, that these four planets are the fragments of a large celestial body which once revolved between Mars and Jupiter, and which burst asunder by some tremendous convulsion, or some external violence. The discovery of Ceres by Piazzi, on the first day of the present century, drew the attention of all the

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CCXII. Why did Bode infer that there was a planet wanting between Mars and Jupiter? **CCXIII.** In what particulars do these planets differ from the other planets? How is it possible that two of them should ever come into collision? **CCXIV.** How is it that Vesta is sometimes farther from the Sun than either Ceres, Pallas or Juno, when her mean distance is many millions of miles less than theirs? What is the position of her orbit with regard to their orbits? **CCXV.** What theory in regard to the origin of these planets have astronomers derived from these and some other circumstances?

astronomers of the age to that region of the sky, and every inch of it was minutely explored. The consequence was, that, in the year following, Dr. Olbers, of Bremen, announced to the world, the discovery of Pallas, situated not many degrees from Ceres, and very much resembling it in size.

CCXVI. From this discovery, Dr. Olbers first conceived the idea that these bodies might be the fragments of a former world; and if so, that other portions of it might be found either in the same neighbourhood, or else, having diverged from the same point, "they ought to have two common points of reunion, or two nodes in opposite regions of the heavens through which all the planetary fragments must sooner or later pass."

CCXVII. One of these nodes he found to be, in the constellation Virgo, and the opposite one, in the Whale; and it is a remarkable coincidence that it was in the neighbourhood of the latter constellation that Mr. Harding discovered the planet Juno. In order therefore to detect the remaining fragments, if any existed, Dr. Olbers examined, three times every year, all the small stars in Virgo and the Whale; and it was actually in the constellation Virgo, that he discovered the planet Vesta. Some astronomers think it not unlikely that other fragments of a similar description may hereafter be discovered.

CCXVIII. Dr. Brewster attributes the fall of meteoric stones to the smaller fragments of these bodies happening to come within the sphere of the Earth's attraction.

Observation 1. Meteoric stones, or what are generally termed *aerolites*, are stones which sometimes fall from the upper regions of the atmosphere, upon the Earth. The substance of which they are composed is for the most part, *metallic;* but the ore of which it consists is not to be found *in the same constituent proportions* in any known substance upon the Earth.

2. Their fall is generally preceded by a luminous appearance, a hissing

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CCXVI. Who first conceived this idea, and from what circumstances? Where did he imagine other fragments might be found? CCXVII. In what constellations did he find these nodes to be, and where were Juno and Vesta actually found? How did Dr. Olbers discover Vesta? CCXVIII. To what does Dr. Brewster attribute the fall of meteoric stones? What is meant by the expression meteoric stones, and of what substances are they composed? What indications generally precede their fall?

noise, and a loud explosion; and when found immediately after their descent, they are always hot and usually covered with a black crust indicating a state of exterior fusion.

3. Their size differs from that of small fragments of inconsiderable weight, to that of the most ponderous masses. Some have been found to weigh from [illegible] pounds to several tons; and they have descended to the Earth with a force sufficient to bury them many feet under the surface.

4. Some have supposed that they are projected from volcanoes in the Moon; others that they are projected from volcanoes on the Earth; while others suggest that they are generated in the regions of the atmosphere; but the truth is probably not yet ascertained. In some instances, these stones have penetrated through the roofs of houses, and proved destructive to the inhabitants.

5. If we carefully compute the force of gravity in the Moon, we shall find that if a body were projected from her surface with a momentum that would cause it to move at the rate of 5,200 feet in the first second of time, and in the direction of a line joining the centres of the Earth and Moon, it would not fall again to the surface of the Moon; but would become a satellite to the Earth. Such an impulse might indeed cause it even after many revolutions, to fall to the Earth. The fall, therefore, of these stones from the air, may be accounted for in this manner.

6. Mr. Harte, calculates, that even a velocity of 6000 feet in a second, would be sufficient to carry a body projected from the surface of the Moon beyond the power of her attraction. If so, a projectile force three times greater than that of a cannon, would carry a body from the Moon beyond the point of equal attraction, and cause it to reach the Earth. A force equal to this is often exerted by our volcanoes, and by subterraneous steam. Hence, there is no impossibility in the supposition of their coming from the Moon.

CCXIX. Vesta appears, however, like a star of the 5th or 6th magnitude, shining with a pure steady radiance, and is the only one of the asteroids which can be discerned by the naked eye.

CCXX. Juno, the next planet in order after Vesta, revolves around the Sun in 4 years, $4\frac{1}{2}$ months, at the mean distance of 254,000,000 of miles, moving in her orbit at the rate of forty-one thousand miles an hour. Her diameter is estimated at 1393 miles. This would make her magnitude 183 times less than the Earth's. The light and heat which she receives from the Sun is seven times less than that received by the Earth.

The eccentricity of her orbit is so great, that her greatest distance from the Sun is nearly double her least dis-

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In what state are they found to be after their descent? What is their magnitude? What theories have been adopted to account for their origin? Explain how it is not impossible that they may come from the Moon. CCXIX. Describe the appearance of Vesta. CCXX. What is the next planet in order after Vesta, and what is said of her?

tance; so that, when she is in her *perihelion*, she is nearer the Sun by 130,000,000 of miles, than when she is in her *aphelion*. This great eccentricity has a corresponding effect upon her rate of motion; for being so much nearer, and therefore so much more powerfully attracted by the Sun at one time than at another, she moves through that half of her orbit which is nearest the Sun, in one half of the time that she occupies in completing the other half.

Observation. According to Schroeter, the diameter of Juno is 1425 miles; and she is surrounded by an atmosphere more dense than that of any of the other planets. Schroeter also remarks, that the variation in her brilliancy is chiefly owing to certain changes in the density of her atmosphere; at the same time he thinks it not improbable that these changes may arise from a diurnal revolution on her axis.

CCXXI. Ceres, the next planet in order after Juno, revolves about the Sun in 4 years 7⅓ months, at the mean distance of 263,500,000 miles, moving in her orbit at the rate of 41,000 miles an hour. Her diameter is estimated at 1582 miles, which makes her magnitude 125 times less than the Earth's. The intensity of the light and heat which she receives from the Sun, is about 7½ times less than that of those received by the Earth.

CCXXII. Ceres shines with a ruddy colour, and appears to be only about the size of a star of the 8th magnitude. Consequently she is never seen by the naked eye. She is surrounded by a species of cloudy or nebulous light, which gives her somewhat the appearance of a comet, forming, according to Schroeter, an atmosphere 675 miles in height.

Observation. Ceres, as has been said, was the first discovered Asteroid. At her discovery, astronomers congratulated themselves upon the harmony of the system being restored. They had long wanted a planet to fill up the great void between Mars and Jupiter, in order to make the system complete in their own eyes; but the successive discoveries of Pallas and Juno again introduced confusion, and presented a difficulty which they were unable to solve, till Dr. Olbers suggested the idea that these small anomalous bodies were merely the fragments of a larger planet, which had been exploded by some mighty convulsion. Among the most able and decided advocates of this hypothesis, is Dr. Brewster, of Edinburgh.

What is her diameter, according to Schroeter, and what is the density of her atmosphere, compared with that of the other planets? CCXXI. Describe Ceres. CCXXII. Describe her appearances. What observation on Ceres?

CCXXIII. Pallas, the next planet in order after Ceres, performs her revolution around the Sun in 4 years, 7½ months, at the mean distance of 264,000,000 of miles, moving in her orbit at the rate of 41,000 miles an hour. Her diameter is estimated at 2025 miles, which is but little less than that of our Moon. It is a singular, and very remarkable phenomenon in the solar system, that two planets, (Ceres and Pallas,) nearly of the same size, should be situated at equal distances from the Sun, revolve about him in the same period, and in orbits that intersect each other. The difference in the respective distances of Ceres and Pallas is less than a million of miles. The difference in their sidereal revolutions, according to some astronomers, is but a single day!

JUPITER.

CCXXIV. Jupiter, the largest of all the planets, is situated between the orbits of the asteroids and that of Saturn. He is stated in some of the books to be 89,000 miles in diameter. But the estimation of 86,255 miles is a closer approximation to the truth as this is his mean diameter which is 11 times greater than that of the Earth and his volume is 1,300 times greater. Distance from the Sun in round numbers 490,000,000 of miles, but his exact mean distance is 495,533,837 miles. His distance from the Earth is 395,000,000 of miles. He revolves on his axis in 9 hours 55 minutes and 50 seconds, which gives the inhabitants of its equatorial region a motion by exact calculation of 26,554 miles an hour which is 25 times faster than the motion of our equatorial inhabitants.

CCXXV. Jupiter is the brightest of the planets except Venus. Though his distance from the Sun is so much greater that the light and heat received from him is calculated to be about 25 times less than that received by us.

CCXXIII. Describe Pallas. CCXXIV. Give the diameter, the annual revolution and distance from the Sun, size and diurnal revolution of Jupiter. CCXXV. What are his brilliancy, light and heat?

CCXXVI. This planet when viewed through a telescope appears surrounded by a number of belts or zones which change in their number and in their appearance very considerably. These belts are parallel to each other as well as parallel to the equator of the planet, and they are most generally regarded by astronomers as luminous clouds, and some suppose the peculiar shape to result from the rapid revolution of the planet upon his axis.

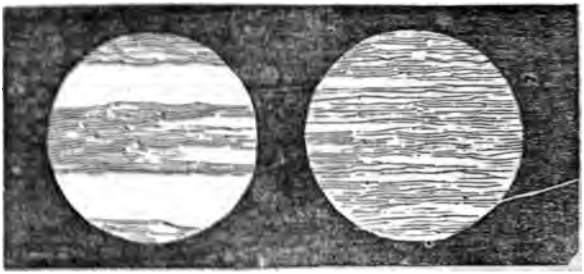
Fig. 27.

CCXXVII. The variation of Jupiter's belts is quite remarkable. At one time seven or eight are distinctly seen; at another, the number is reduced to two or three. The most common appearance is that represented in fig. 27, where some are seen quite regular and extending across the disk, while others are broken and interrupted. Dr. Herschel once saw the whole disk covered with fine parallel and undulating lines as seen in fig. 28 the right hand figure, but soon exhibited the broken appearance seen in the left hand figure.

CCXXVIII. With regard to the cause of the belts we can only say that our positive information on the subject is extremely small, opinions being rather the result of theory than evidence.

CCXXVI. How distinguished? CCXXVII. Is the appearance of Jupiter's belts always the same, or do they change? CCXXVIII. What is said of the cause of Jupiter's belted appearance?

Fig. 28.



CCXXIX. Jupiter is attended by four satellites or moons which revolve around him as our moon does around the Earth. The number of the moons and the frequency of their revolutions cause some one or more to be visible on the surface of the planet every hour of the night. The first is situated nearest to the primary being 259,000 miles from his centre, and about 214,000 miles from his surface, and revolves about it in 42½ hours appearing four times larger than our moon does to us. The second is smaller and farther off appearing of the size of our moon. The third is still less in size and at a greater distance; the fourth is at the greatest distance of all, being 1,164,000 miles from the primary around which it revolves in 16 days and three fourths, and appears at the surface of Jupiter but a little more than half as large as our moon does to us.

CCXXX. These satellites are frequently eclipsed by passing into the shadow of their primary in the same manner as our moon is eclipsed by passing through the shadow of the Earth. The three first or nearest are eclipsed during each revolution, while the fourth is eclipsed only four times in every six revolutions of the satellite about its primary.

CCXXIX. How many moons has Jupiter, and what are the periods of their revolutions? CCXXX. What occasions the eclipses of Jupiter's moons?

CCXXXI. By means of these eclipses astronomers have ascertained the longitude of places on the Earth, and the velocity of light.

CCXXXII. The velocity of light was ascertained in the following manner. It was first observed by Roemer that when the earth is in that part of her orbit nearest to Jupiter the eclipse of its nearest satellite occurs 8 minutes and 13 seconds sooner than it ought according to calculation; again, when the earth is in that part of her orbit farthest from Jupiter the eclipse of the same satellite occurred 8 minutes and 13 seconds later than the calculated time. The total difference between apparent and calculated time is 16 minutes and 26 seconds, and the only circumstance that could affect the observations in either case is the different distance of the Earth from the eclipse; which difference is equal to the diameter of the Earth's orbit or about 190,000,000 of miles; and this difference could not be accounted for on any other principle than by supposing that light was 16 minutes and 13 seconds in crossing the Earth's orbit and 8 minutes $6\frac{1}{2}$ seconds in proceeding from the Sun to the Earth, a distance of 95,000,000 of miles. This motion is at the rate of 12,000,000 of miles per minute, and about 200,000 miles per second.

SATURN.

CCXXXIII. The planet Saturn is situated between the orbit of Jupiter and Herschel, and revolves around the Sun, at the distance of a little more than 900,000,000 of miles, in about 30 terrestrial years, and his diameter is 79 or 80,000 miles, making his bulk, from 900 to 1,000 times greater than that of the Earth.

CCXXXIV. The period of Saturn's revolution on his axis, which measures his day, is little more than 10 hours,

CCXXXI. Of what use are these eclipses to astronomers? CCXXXII. How is the velocity of light ascertained by eclipses of Jupiter's satellites? CCXXXIII. What is the time of Saturn's periodic revolutions round the Sun? his distance from the Sun, and what his diameter? CCXXXIV. What is the period of his diurnal revolution, and how many days make a year of Saturn, and how many moons has he?

25,150 of his days constitute his year. From its great distance from the Sun, it appears like a fixed star, from which it may be distinguished by its pale feeble and steady light, and by calculation receives 90 times less heat and light than does the Earth, but even that amount of light, is calculated to be equal to 3,000 of our full moons, and besides, this planet is supplied with seven moons which revolve around him in periods varying from 1 to 79 of our days; and at distances varying from 120,000 to 2,000,000 of miles from their primary.

CCXXXV. The telescopic appearance of Saturn is extremely beautiful; he is distinguished from all the other planets by his great zone or ring, like an immensely expanded and luminous rainbow, which surrounds him with a perpetual light, more brilliant than that of the planet itself, a representation of which is given in fig. 29.

Fig. 29.

CCXXXVI. This ring is double or composed of two luminous circles, one within the other with a dark space of 2,800 miles intervening; the distance from the primary to his inner ring is between 20 and 30,000 miles.

CCXXXVII. The circumference of the outer ring is said to be 640,000 miles, and its breadth from the external to the internal portion between 7 and 8,000. These rings rotate around the planet in $10\frac{1}{2}$ hours.

CCXXXV. How is Saturn particularly distinguished from all the other planets? CCXXXVI. What distance is there between the body of Saturn and his inner ring, and what distance is there between his inner and outer ring? CCXXXVII. What is the circumference of the outer ring? CCXXXVIII. What is the design of Saturn's ring?

CCXXXVIII. The most obvious use of Saturn's rings is to supply that planet with light reflected from their surfaces to make up the deficiency of direct light from the Sun. The Sun illuminates one side of the ring for 15 of our years, and the opposite side in the next 15 years, in consequence of the inclination of the rings to the plane of the ecliptic which is about 31 degrees.

CCXXXIX. Not only the rings but also the planet has one of his sides illuminated during 15 of our years, (which is one half of Saturn's year,) and the opposite side during the next 15 years. Thus, his poles like those of our own planet, will be alternately light and dark, but for 15 years instead of half a year.

Illustration. The woodcut fig. 30, exhibits a view of Saturn and his double ring in which the latter is represented with its edge towards the spectator. He sees the illuminated planet within them, the dark space between it, and the inner ring and without this, the narrow dark space between the inner and outer ring.

Fig. 30.

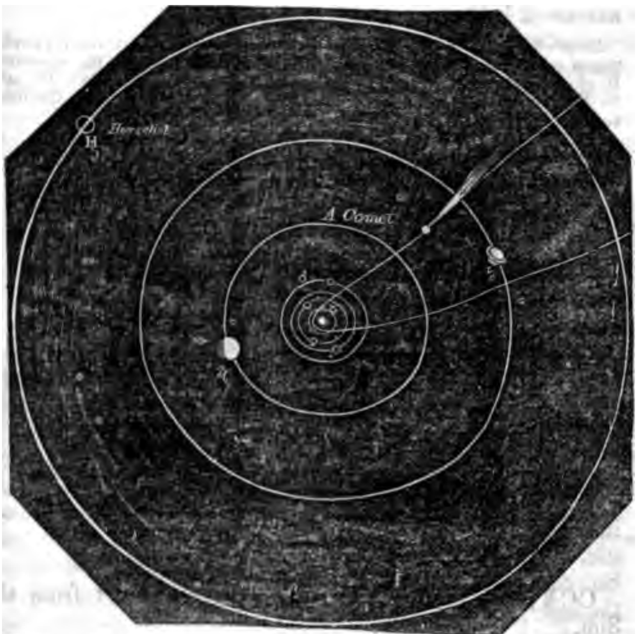
HERSCHEL.

CCXL. Herschel is the most distant planet from the Sun.

CCXXXIX. What is said of the illumination of his rings? Give the illustration by fig. 30. CCXL. What is said of Herschel?

CCXLI. Herschel completes his annual revolution around the Sun in 84 years and 1 month of our time; and moves in his orbit at the rate of a little more than 15,000 miles per hour. His diameter is between 34 and 35,000 miles, and his bulk 80 times greater than that of the Earth. To a spectator on this planet, the Sun would appear more than 360 times less than he does to us, and the light and heat received would, of course, be in the same proportion. The strength of this light has been differently calculated; while one has estimated it equal to 800 of our full moons another estimates it at only 248.

Fig. 31.



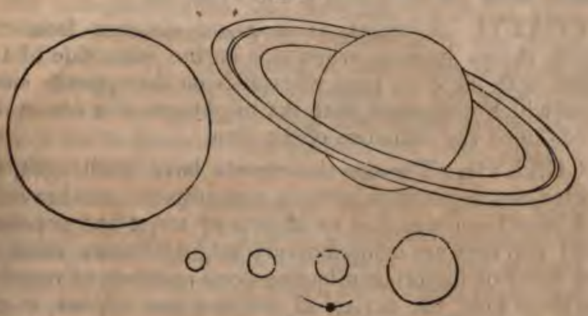
CCXLI. What is said of his revolution, diameter, light and heat? CCXLII. What is said of the satellites of Herschel?

CCXLII. Herschel has six satellites constantly revolving around him as their primary in different times and at different distances. Four of them were discovered by Dr. Herschel, and two by his sister, Miss Caroline Herschel. Others may yet be discovered.

Illustration. Fig. 31, is given to represent the relative position of the planets in their orbits, (except the asteroids,) and their comparative size and distances from the Sun, with the orbit of a comet approaching the Sun. The orbits of the planets are marked by the respective signs of each. Mercury is the nearest, Venus next, the Earth the third, Mars the fourth, Jupiter fifth, Saturn sixth, and Herschel seventh. The asteroids are situated between the orbits of Mars and Jupiter.

Fig. 32 is given to show the comparative sizes of the planets.

Fig. 32.



OF COMETS.

CCXLIII. *Comets* are solid, opaque, planetary bodies, revolving about the Sun in elliptical orbits of immense circumference.

CCXLIV. The motions of the comets are very complicated; their orbits, instead of being nearly circular, like those of the planets, are remarkably long and eccentric. Some of the comets approach much nearer to the Sun than the nearest planet—so much so, as to be hid in the solar rays; again, they recede to so great a distance

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Give the illustration by fig. 31, and the object of fig. 32. CCXLIII. What are the Comets? CCXLIV. What is said of the motions of comets and the phenomena exhibited by them?

from that luminary as to be carried far beyond the bounds of the planetary system, where they become wholly in visible, and seem entirely lost from the system. After a lapse of ages, they are sometimes again observed in the planetary regions.

CCXLV. The comets appear in different parts of the heavens and move in various directions. They differ, as the stars do, in magnitude and brightness; and they are principally distinguished from the planets by a luminous train or blaze, called a *tail;* or by some hairy or nebu lous appearance; and by their always disappearing after having been visible during a short time only.

CCXLVI. A comet, at a given distance from the Earth, shines brighter when it is on the same side of the Earth with the Sun, than when it is on the opposite side, from which it appears that the brightness of a comet de pends upon the influence of the Sun.

CCXLVII. Though the comets have in all ages, at tracted much attention by their appearance in the heavens, and have been regarded as objects of terror and supersti. tion; still they are comparatively but little known, scarcely any thing of importance having been ascertained respecting them until the revival of learning and science, in the sixteenth century, when particular attention began to be paid to Astronomy. We are as yet totally ignorant of the number and of the uses of the comets in the solar system, or in the fabric of the world, if indeed they have any use whatever. Nor is it to be expected that their number will soon be ascertained, as some of them are whole centuries before they make their reappearance. The number of comets that have been seen, and are recorded, appears to be very considerable. Ricciolus, an Italian astronomer and mathematician, makes mention in his writings, of about 154, which had appeared previous to the year 1651; but Lubienietz reckons 415 until the year

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CCXLV. How is a comet described? CCXLVI. From what circumstance is it inferred that the brightness of a comet depends upon the influence of the Sun? CCXLVII. What is hitherto known respecting the number and uses of the comets?

1665. The Chinese astronomical books record the appearance of 200 or 300 comets.

CCXLVIII. Of all the comets which are supposed to exist, though lately discovered to be much more numerous than has formerly been supposed, the periods of only *four* or *five* have been ascertained with any degree of certainty; though the elements of more than 100 have been calculated.

CCXLIX. The first comet whose period of revolution has been determined with certainty, is that of the year 1682, which had been already observed in 1607, by Kepler and Longomontanus, and in 1534, by Peter Apian, and which reappeared in 1759, according to the prediction of Dr. Halley. The period of this comet is about 76 years. Another comet that appeared in the year 1264 is supposed to be the same with that which appeared in 1556; if so, its periodic time is about 292 years, and consequently it may be expected to return in 1848.

The appearance of one comet has been several times recorded in history. This is the celebrated comet of the year 1680, which, from the accounts of various authors, and from the circumstances which attended its apparition, seems to be the same with that which appeared in the year 44 B. C., or at the time of Julius Cesar, and in the years 531 and 1106 of the Christian era; also in 619 and 2340 before the birth of Christ. As there is an interval of 575 years between all these periods except the last, Dr. Halley was therefore led to consider the comet of 1680 as the one that had appeared at the times above-mentioned, that its period is about 575 years, and that it will not again make its appearance until the year 2254. This comet, when nearest to the Sun in 1680, was only one sixth part of the solar diameter distant from the surface of the Sun; and when farthest, its distance exceeds 138 times the distance of the Sun from the Earth; and

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CCXLVIII. How many comets are known to return at certain periods? CCXLIX. What account is given of each of those comets?

according to Dr. Halley, it is 22,412 times farther from the Sun, when in its aphelion, than in its perihelion, its greatest distance from the Sun being not less than 13,000,000,000 of miles. According to Newton, the velocity of this comet, when in the part of its orbit which is nearest to the Sun, is at the rate of 880,000 miles an hour; but according to Squire, it is not less than 1,240,000 miles an hour; and Newton calculated, that while in this part of its orbit, it was exposed to a degree of heat 2000 times greater than that of red-hot iron.

CCL. The periodic returns of three other comets are supposed to be ascertained. One of these has a period of about 20 years; another, known as *Encke's comet*, revolves round the Sun once in about 1204 days, and the third, generally designated the *Comet of Biela*, has a periodic time about double that of Encke's comet.

CCLI. The tails of comets are sometimes of a most prodigious length; that of the comet of 1680, which subtended at Paris an angle of 62°, and at Constantinople one of 90°, was at least 100,000,000 of miles in length. Various opinions have been entertained by different philosophers respecting the cause of these extraordinary appendages, called *tails*. Some have conjectured the tail of a comet to be smoke rising from the body of the comet in a line opposite to the Sun. Others regard them as being composed of vapours elevated to a considerable height by the violence of the heat to which they are exposed in their near approaches to the Sun. Dr. Hamilton considers the tails of comets, the *aurora borealis*, and the electric fluid, to be matter of the same kind. Sir Richard Philips published in the Monthly Magazine the opinion, that this wonderful appendage of comets, is occasioned by the refraction, and consequent condensation of the Sun's light through the dense atmosphere of the comet;—hence the tail is always in an exact straight line opposite to the Sun; and hence, on the principle of a convex lens, the

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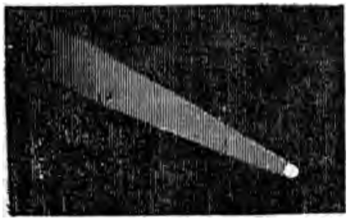
CCL. What is said of Encke and Biela's comets? CCLI. What is said of comets' tails?

tail lengthens as it approaches the Sun, and shortens as it departs.

Illustration. The following is the appearance of a comet when in the neighbourhood of the Sun and visible to us.

Fig. 33.



OF THE FIXED STARS.

CCLII. Those luminous points, or shining bodies, which always appear in the heavens at the same distance from each other, are called *Fixed Stars;* because they do not appear to have any proper motion of their own.

Observation 1. The fixed stars are luminous bodies. Because they appear as points of small magnitude, when viewed through a telescope, they must be at such immense distances as to be invisible to the naked eye if they borrowed their light; as is the case with respect to the satellites of Jupiter and Saturn, although they appear of very distinguishable magnitude through a telescope. Besides, from the weakness of reflected light, there can be no doubt that the fixed stars shine with their own light. They are easily known from the planets, by their twinkling.

2. The number of stars, visible at any one time to the naked eye, is about 1000; but Dr. Herschel, by his skilful and magnificent improvements of the reflecting telescope, has discovered that the whole number is great beyond all conception.—The comparative brightness of the stars is, Sirius 1.00, Canopus .98, Centauri .96, Acherni .94, &c.

3. The magnitudes of the fixed stars appear to be different from each other, which difference may arise either from a diversity in their real magnitudes, or distances; or from both these causes acting conjointly. The difference in the apparent magnitude of the stars is such as to admit of their being divided into six classes, the largest being called stars of the *first magnitude,* and the least, which are visible to the naked eye, stars of the *sixth magnitude.* Stars only visible by the help of glasses, are called *Telescopic Stars.* Dr. Halley very justly remarks, that the stars must be infinite in number to maintain their equilibrium in space. And Dr. Herschel

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CCLII. Which of the celestial bodies are named fixed stars, and why are they so called? How is it proved that the fixed stars are luminous bodies? What is the number of stars visible at any one time to the naked eye? How are the stars distinguished with regard to their apparent magnitudes? What general name is applied to those stars which are visible only through telescopes?

thinks he has seen stars 42,000 times as far off as Sirius. In one instance a cluster of 5,000 stars, in a mass, was barely visible in the 40 feet telescope, and consequently must have been eleven trillions of miles off!

4. To the bare eye, the stars appear of some sensible magnitude, owing to the glare of light arising from the numberless reflections of the rays in coming to the eye; this leads us to imagine that stars are much larger than they would appear if we saw them only by the few rays which come directly from them, so as to enter the eye without being intermixed with others. Examine a fixed star of the first magnitude through a long and narrow tube, which, though it takes in as much of the sky as would hold a thousand such stars, scarcely renders that one visible.

5. There seems but little reason to expect that the real magnitudes of the fixed stars will ever be discovered with certainty, we must, therefore, be contented with an approximation, deduced from their parallax, if this should ever be ascertained, and the quantity of light they afford us compared with that of the Sun. To this purpose, Dr. Herschel informs us, that, with a magnifying power of 6450, and by means of his new micrometer, he found the apparent diameter of a Lyræ, to be 0″.355, or the third of a second.

6. The ingenious observations of Kepler upon the magnitudes and distances of the fixed stars, deserve to be introduced here, and the more so as he has been followed in the conjecture by the great Dr. Halley. He observes that there can be only 13 points upon the surface of a sphere as far distant from each other as from the centre; and supposing the nearest fixed stars to be as far from each other as from the Sun, he concludes there can be only 13 stars of the first magnitude. Hence, at twice that distance from the Sun, there may be placed four times as many, or 52; at three times that distance, nine times as many, or 117; and so on. These numbers will give pretty nearly the number of stars of the first, second, third, &c. magnitudes.* Dr. Halley farther remarks, that if the number of stars be finite, and occupy only a part of space, the outward stars would be continually attracted to those within, and in time would unite into one. But if the number is infinite, and they occupy an infinite space, all the parts would be nearly in equilibrio, and, consequently, each fixed star being drawn in opposite directions would keep its place or move on till it had found an equilibrium.

CCLIII. The ancients, that they might the better distinguish the stars with regard to their situation in the heavens, divided them into several constellations, that is, masses or clusters of stars, each mass consisting of such as are near to each other. And to distinguish these groups or systems from each other, they gave them the names of such men or things as they fancied the space they took up in the heavens represented. To these, several new constellations have been added by modern astronomers.

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* This statement appears to be erroneous, for, in this case, the whole number of stars visible to the naked eye from all sides of the Earth, would not much exceed 1985, the sum of the above numbers.

What is said of the distance and number of the fixed stars? What reason have we to suppose that the number of stars is infinite? CCLIII. What is a constellation?

Observation 1. The ideal delineations of those figures of animals and other objects, which include the *constellations* or *asterisms*, are dispersed all over the heavens, and a particular situation is assigned to each, as may be seen upon a common celestial globe, or upon a planisphere or map of the heavens; yet some spaces in the heavens remained here and there, which, according to the ancient distribution of the stars, were out of the bounds of the contiguous constellations. The stars which were included in those spaces were called *Unformed Stars;* but, as represented on the modern celestial globes, the constellations are made to comprehend all the unformed or extra-constellated stars.

2. Besides the names of the constellations, the ancient Greeks gave particular names to some single stars, or small collections of stars. Thus, the cluster of small stars in the neck of Taurus, the Bull, was called the *Pleiades;* five stars in the Bull's Face, the *Hyades;* a bright star in the Breast of Leo, the *Lion's Heart,* or *Cor Leonis;* and a large star between the Knees of Bootes, *Arcturus,* &c. Several of the brightest fixed stars have also particular names, as Sirius, Aldebaran, Regulus, Castor, Procyon, Aloth, &c.

3. As it would be an endless task to give a proper name to each star, astronomers, in order that the memory may not be burdened with a multiplicity of names, denominate the stars of each constellation by means of the letters of the Greek alphabet, which are applied to them according to their apparent relative size. The principal or brightest star in the constellation is designated by α *Alpha;* the next in brightness, by β *Beta;* the third, by γ *Gamma;* and so on. When the number of stars in a constellation, exceeds the letters in the Greek alphabet, the letters of the Roman alphabet, a, b, c, d, &c., are applied to the remaining stars in the same manner; and when these are not sufficient, the numbers, 1, 2, 3, 4, 5, &c., are used to designate the rest in the same regular succession; so that by these means, the stars may be readily known and spoken of with as much ease as if each had a separate name.*

4. The celestial sphere is usually divided into three portions, the *zodiac,* and the *northern* and *southern hemispheres,* or more properly the two regions to the north and south of the zodiac. Astronomers have accordingly divided the constellations into three classes, called the *northern,* the *southern,* and the *zodaical.* The number of northern constellations is 37, of the southern 47, and of the zodaical 12; making 96 in the whole. The ancient astronomers reckoned only 48 constellations—12 in the zodiac, 21 to the north, and 15 to the south. Modern astronomers, however, by curtailing several of the ancient constellations of some of their stars, which they distributed into new constellations, and by arranging into constellations the unformed stars, or those which were between the ancient constellations, have increased their number to 96, as above stated.

The term *zodiac* is derived from a Greek word signifying an animal, because most of the constellations in that zone, which are twelve in number,

* The method of designating the stars in each constellation by the Greek and Roman alphabets was the invention of John Bayer, a German lawyer and astronomer, who introduced it into his *Uranometria,* or charts of the constellations, first published in 1603, in folio. But in our opinion, why not avoid all this perplexity and confusion of Greek, Roman, and numerical characters, by adopting at once the numerical characters?

What is the use of distributing the fixed stars into constellations? What is meant by unformed stars? Are all the stars included in the several constellations? How are the several stars in each constellation distinguished? How have astronomers contrived to be understood, when speaking of any particular star in a constellation?

are represented by the outlines of the figures of animals; as, *Aries*, the Ram; *Taurus*, the Bull; *Gemini*, the Twins; *Cancer*, the Crab; *Leo*, the Lion; *Virgo*, the Virgin; *Libra*, the Balance; *Scorpio*, the Scorpion; *Sagittarius*, the Archer; *Capricornus*, the Goat; *Aquarius*, the Waterbearer; and *Pisces*, the Fishes.

5. The luminous part of the heavens, called the *Milky-Way*, consists of fixed stars too small to be seen by the naked eye. In a paper on the constructions of the heavens, Dr. Herschel says: "It is very probable, that the great stratum called the Milky-Way, is that in which the Sun is placed, though perhaps not in the centre of its thickness, but not far from the place where some smaller stratum branches from it. Such a supposition will satisfactorily, and with great simplicity account for all the phenomena of the Milky Way, which, according to this hypothesis, is no other than the appearance of the projection of the stars contained in this stratum, and its secondary branch."

6. In another paper on the same subject, he says:—"We will now retreat to our own retired station in one of the planets attending a star in the great combination with numberless others; and in order to investigate what will be the appearances from this contracted situation, let us begin with the naked eye. The stars of the first magnitude, being, in all probability, the nearest, will furnish us with a step to begin our scale; setting off, therefore, with the distance of Sirius or Arcturus, for instance, as unity, we will at present suppose, that those of the second magnitude are at double, and those of the third at treble the distance, and so forth. Taking it then for granted, that a star of the seventh magnitude is about seven times as far from us as one of the first, it follows that an observer, who is enclosed in a globular cluster of stars, and not far from the centre, will never be able, with the naked eye, to see the end of it; for since, according to the above estimations, he can only extend his view about seven times the distance of Sirius, it cannot be expected that his eyes should reach the borders of a cluster, which has perhaps, not less than fifty stars in depth every where around him. The whole universe, therefore, to him, will be comprised in a set of constellations, richly ornamented with scattered stars of all sizes. Or, if the united brightness of a neighbouring cluster of stars should, in a remarkably clear night, reach his sight, it will put on the appearance of a small, faint, nebulous cloud, not to be perceived without the greatest attention. Allowing him the use of a common telescope, he begins to suspect, that all the milkiness of the bright path which surrounds the sphere may be owing to stars. By increasing his power of vision, he becomes certain, that the Milky-Way is, indeed, no other than a collection of very small stars, and the nebulæ nothing but clusters of stars."

7. Dr. Herschel then solves a general problem for computing the length of the visual ray:—that of the telescope, which he used, will reach to stars 497 times the distance of Sirius. Now Sirius cannot be nearer than $100{,}000 \times 190{,}000{,}000$ miles, therefore, Dr. Herschel's telescope will at last reach to $100{,}000 \times 190{,}000{,}000 \times 497$ miles.* And Dr. Herschel says, that in the most crowded part of the Milky-way he has had fields of view that contained no less than 588 stars, and these were continued for many minutes, so that in a quarter of an hour, he has seen 116,000 stars pass through the field-view of a telescope of only 15′ aperture; and at another time, in 41 minutes, he saw 258,000 stars pass through the field of his telescope. Every

* This part of the observation seems to be quite exceptionable, and inconsistent with Dr. Herschel's own observations elsewhere on the same subject.

What is it that produces the luminous appearance called the milky-way?

improvement in his telescope has discovered stars not seen before, so that there appear no bounds to their number, or to the extent of the universe.

8. There are spots in the heavens, called *Nebulæ*, some of which consist of clusters of telescopic stars; others appear as luminous spots of different forms. The most considerable one is that which is about midway between the two stars on the Blade of Orion's Sword, marked θ by Bayer, and discovered in the year 1656 by Huygens. It consists only of 7 stars; and the other part is a bright spot upon a dark ground, and appears like an opening into brighter regions beyond. Dr. Halley and others have discovered nebulæ in different parts of the heavens. In the *Connoisance des Temps*, for 1783 and 1784, there is given a catalogue of 103 nebulæ observed by Le Messier and M. Mechain. But to Dr. Herschel we are indebted for catalogues of 2000 nebulæ and clusters of stars, which he himself had discovered. Some of them form a round compact system; others are more irregular, of various forms; and some are long and narrow. The appearance of luminous spaces in the heavens, Sir Richard Philips denies to arise from light *per se;* but ascribes the luminosity of all such spaces to the multitude of planets, asteroids, satellites, and cometary bodies, with which those spaces are filled.

9. New stars sometimes appear, while others disappear. Several stars, mentioned by the ancient astronomers, are not to be found; several are now visible to the naked eye, which are not mentioned in the ancient catalogues; and some stars have suddenly appeared, and again after a considerable interval, vanished; also a change of place has been observed in some stars.

10. From an attentive examination of the stars with good telescopes, many which appear only single to the naked eye, are found to consist of numerous stars. α *Herculis*, is a double star, so is π *Bootes;* and Dr. Herschel, by his highly improved telescopes, has found about 700.

From a series of observations on double stars, Dr. Herschel has found that a great many of them have changed their situations with regard to each other; that the one performs a revolution round the other; and that the motion of some is direct, while that of others is retrograde. He has observed that there is a change in more than 50 of the double stars, either in the distance of the two stars, or in the angle made by a line joining them with the direction of their daily motion.

Dr. Herschel has observed that the smaller of the two stars composing Castor, has a revolution of 342½ years round the other; the double star γ Leonis has a period of 1200 years; ϵ Bootes, of 1681 years; δ Serpentis of 375 years; γ Virginis, of 708 years, and so of the rest:—but the life of one man is evidently too short to attain correct results, in regard to periods so disproportionate to his narrow space of existence.

11. These motions of the stars among themselves being apparent to observation, the doctrine of Dr. Herschel and other astronomers is rendered probable, that the Sun has a motion or orbit of its own among the fixed stars of the Milky-Way, at the rate of the Earth's motion, carrying with it all the planets, just as the planets themselves, carry with them their systems of satellites in their own orbits. The rotation of the Sun on its inclined axis, according to the theory of Sir Richard Philips, seems to indicate the action of a centrifugal force in the Sun, and to render the notion, that the whole solar system is analogous to a primary and its satellites, exceedingly probable.

What are those spots called nebulæ, which are seen in different parts of the heavens? What is said concerning the appearance of new stars? What is said concerning double stars, their revolutions round each other, and their proper motions in general? What inference is drawn from the proper motions of the fixed stars?

In a paper on the Construction of the Heavens, Dr. Herschel has the following observation:—"That the Milky-Way is a most extensive stratum of stars of various sizes, admits no longer of the least doubt; and that our Sun is actually one of the heavenly bodies belonging to it, is as evident."

The following figure represents a COMPRESSED CLUSTER OF STARS, the centre part 8′ long, 2′ broad:—

Fig. 34.

The following figure represents another similar CLUSTER OF STARS:—

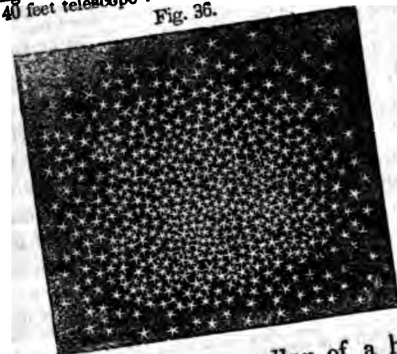
Fig. 35.

What is the hypothesis of Dr. Herschel, respecting the "construction of the heavens?"

12. In February, 1814, Dr. Herschel, the prince of astronomers, read to the Royal Society, the results of thirty years' observations on nebulæ, with the best telescopes ever possessed by man. He conceives that the stars form independent systems among themselves. He considers our Sun as part of that shoal or system which we call the Milky-Way, and that all the stars of the first, second and third magnitude, belong to that vast cluster. The stars, he remarks, are not spread in equal portions over the celestial sphere, but are found in patches, each containing many thousands, and many more than the eye can separate from the mass. These he calls *Clusters*; and he conceives they have a constant disposition to unite more, by a power, which he calls the *Clustering Power*. He gives an account of eighty of these clusters, some of the drawings of which are copied on this and preceding pages.

The following figure represents a GLOBULAR CLUSTER 2′ in diameter, as seen with Herschel's 40 feet telescope :—

Fig. 36.



CCLIV. The *Annual Parallax* of a heavenly body is the change of its apparent place, as viewed from th Earth in its annual motion; and is the angle which th diameter of the Earth's orbit would subtend, if that diam ter could be viewed from the heavenly body.

CCLV. If the distance of an object is greater th 400,000 times the base, the angles at the stations do sensibly differ from right angles; consequently, the li drawn from the object to the stations, are physic parallel, and the parallax of an object, the distance which is above 400,000 times greater than that betv the two stations of observation, is consequently insens

CCLIV. What is the annual parallax? CCLV. What are the principles upo the annual parallax of a celestial body is ascertained?

Observation. If the object is at a greater distance from either station than 400,000 times the base, the angle at one of the stations being 90°, the angle at the other will be more than 89° 59′ 57″.9, the difference of which angle and 90° being scarcely more than 2″, is too small to become sensible by observation.

CCLVI. If the parallax of an object, observed with an instrument sufficiently exact to measure an angle of 2″, be insensible, the distance of the object from either station cannot be *less* than 400,000 times the base, yet it may be greater in assignable ratio.

Observation. Lines drawn from any given points in a base, to an object, may be esteemed in practice parallel, without any sensible error, if the distance of the object be more than 100,000 times the base. Rays, therefore, diverging from any point in the Sun's disk upon the surface of the Earth, may be esteemed parallel, if their distance from each other does not exceed about 970 miles at the Earth's surface; because 970 is to the distance of the Earth from the Sun in a proportion of 1 to 100,000.

CCLVII. The fixed stars have no sensible annual parallax, because when the place of any star is observed by the best instruments, from opposite points of the Earth's orbit, its apparent place in the heavens remains the same; which could not be the case, if the angle of its parallax were so much as *two seconds*.

Observation 1. Hence it appears that the fixed stars are so remote, that a diameter of the Earth's orbit bears no sensible proportion to their distance: or that a diameter of the Earth's orbit, if viewed from one of the fixed stars would appear as a point.

2. The distance of a star must be greater than 100,000 times the base, from the extremities of which it is observed; that is, greater than 100,000 times the diameter of the orbit of the Earth, or greater than $100{,}000 \times 190{,}000{,}000$, which is nineteen billions of miles as the least possible distance of the nearest fixed star.

3. The parallax of a fixed star, being not more than 2″, the Sun, when viewed from that star, would appear under an angle less than $\frac{32'\ 3''}{200{,}000}$, or less than $\frac{1''}{100}$, and, therefore, could not be distinguished from a point.

4. Since bodies, equal in magnitude and splendour to the Sun, being placed at the distance of the fixed stars, would appear to us as the fixed stars now do; it may be supposed probable, that the fixed stars are bodies similar to the Sun, which is the centre to the solar system. This being the case, the reason will appear, why a fixed star, when viewed through a telescope magnifying 200 times, appears no other than a point. For the apparent diameter of the star being less one hundredth part of a second, when magnified 200 times, will subtend an angle less than 2″, at the eye of the spectator observing it in the telescope.

CCLVII. Why have not the stars any sensible parallax?

EXPLANATION OF TERMS.

Air. An elastic fluid. The atmosphere which surrounds the earth. See pneumatics.
Air Pump. An instrument by which vessels may be exhausted of air.
Altitude. The height in degrees of the sun, or any heavenly body above the horizon.
Angle of Incidence. See Optics, page 115.
Angle of Reflection. See Optics, page 116.
Angle of Vision, or visual angle. The space contained between lines drawn from the extreme parts of any object, and meeting in the eye.
Antarctic Circle. See page 205.
Aphelion. That part of the orbit of a planet which is farthest from the sun.
Apogee. That point in which the sun or moon is farthest from the earth.
Area. The surface forming the boundary of any figure.
Aries. One of the 12 Signs of the Zodiac.
Asteroids. (Like stars.) The name of the planets, Ceres, Juno, Pallas, and Vesta.
Astronomy. See page 185.
Atmosphere. See Pneumatics.
Attraction. See page 12.
Attraction of Cohesion. See page 14.
Attraction of Gravitation. See page 12.
Axis of the Earth, or of any of the planets. An imaginary line passing through their centres, and terminating at their poles; around this they revolve.
Axis of Motion. The imaginary line, around which all the parts of a body revolve.
Balloon. Any hollow globe. The term is generally applied to those which are made to ascend in the air. See *Balloon* in *Index*.
Barometer. Commonly called a weather-glass. See *Barometer* in *Index*, and p. 97.
Body. See Matter.
Burning-glass, or Mirror. A lens, or a mirror, by which the rays of light, and heat, are brought to a focus, so as to set bodies on fire.
Camera Obscura. See page 151.
Capillary Tubes. See page 17.
Catoptrics. That part of the science of Optics which treats of the reflection of light.
Centre of Gravity. See page 31.
Centre of Motion. See page 32.
Central Forces. Those which either impel a body towards, or from, a centre of motion.
Centrifugal. That which gives a tendency to fly from a centre.
Centripetal. That which impels a body towards a centre.
Circle. A figure, the periphery, or circumference of which, is every where equally distant from the point called its centre.
Circumference. That which forms the boundary of a circle, or any other figure.
Comets. See page 261.
Cohesion. See Attraction.
Concave. Hollowed out; the inner surface of a watch-glass is concave.
Convex. Projecting, or bulging out, as the exterior surface of a watch-glass.
Cone. A body somewhat resembling a sugar-loaf; that is, having a round base, and sloping at the sides, until it terminates in a point.
Conjunction. When three of the heavenly bodies are in a straight or right line, if you take either of the extreme bodies, the other two are in conjunction with it; because a straight line drawn from it, might pass through the centres of both, and join them together.
Constellation, or Sign. A collection of stars. See page 189.
Convergent Rays, are those which approach each other, so as eventually to meet.
Curvilinear, consisting of a line which is not straight, as a portion of a circle.
Cylinder. A body in the form of a roller, having flat circular ends, and being of equal diameter throughout.

DEGREE. If a circle of any size be divided into 360 equal parts, each of these parts is called a degree. One quarter of a circle contains ninety degrees.
DENSITY. See page 12.
DIAGONAL. A line drawn so as to connect two opposite angles of a square.
DIAMETER. A straight line passing through the centre and terminated at each end.
DILATATION. The act of increasing in size.
DIOPTRICS. That division of Optics which treats of the refraction of rays of light.
DIVERGENT RAYS. Those which are continually receding from each other.
DIVISIBILITY. Capability of being divided, or of having the parts separated.
DOUBLE REFRACTION. See Optics.
DYNAMICS. That division of the science of Mechanics, which considers bodies as acted upon by forces not in equilibrio. It therefore treats of bodies in motion.
ECHO. A sound reflected back by some substance, or surface.
ECLIPSE. See page 228.
ECLIPTIC. A circle in the heavens. The apparent path of the sun, through the twelve signs of the zodiac.
ELASTICITY. See page 15.
ELECTRICS. Substances in which electricity may be excited, non-conductors.
ELECTRO-MAGNETISM, is the science showing the connexion between Electricity and Magnetism. See *Magnetic Electricity*.
ELLIPSIS. An oval. This figure differs from a circle, in being unequal in its diameters, and in having two centres, or points, called its *foci*.
EQUATOR. That imaginary line which divides the earth into northern and southern hemispheres, and which is equally distant from each pole.
EQUATION OF TIME. The difference between the time shown by a watch and that denoted by a sun-dial; or the difference between mean and true time.
EQUILIBRIUM. When two articles exactly balance each other, they are in equilibrium.
EQUINOX. The two periods of time at which the nights and days are equal. See p. 2[illegible].
EXTENSION, is the property of occupying space.
FLUID. A form of matter, in which its particles readily flow, or slide, over each other. Airs, or gases, are called elastic fluids, because they are readily reduced to a smaller bulk by pressure. Liquids, are denominated non-elastic fluids, because they suffer but little diminution of bulk, by any mechanical force.
FOCUS. That point in which converging rays unite.
FORCE. That power which acts upon a body, either creating or stopping motion.
FOUNTAIN. A jet, or stream of water, forced upward by the action of other water, by air, or some other mechanical agent.
FRICTION. The rubbing of bodies together, by which their motion is retarded. Friction may be lessened, but cannot be destroyed.
FULCRUM. A prop. The point on which a body is supported, and moved.
GAS. Any kind of air; of these there are several. The atmosphere consists of two kinds, mixed, or combined with each other, called oxygen and nitrogen. Every kind of aerial substance that is not readily converted to a liquid is called a gas.
GLOBE. A sphere, or ball.
GRAVITY. See page 13, and the following.
HARMONY. A combination of musical sounds. *Harmony* is the combination of two or more sounds, whereas *melody* is one agreeable sound.
HEMISPHERE. Half a sphere or globe.
HORIZON. This is generally divided into *sensible*, and *rational*. See page 237.
HORIZONTAL. Level; not inclined, or sloping.
HYDRAULICS. See page 75.
HYDROSTATICS. See page 64.
HYDROMETER. An instrument used to ascertain the specific gravity of different fluids.
HYPERBOLA. A peculiar curved figure treated of in conic sections. It is also illustrated in this work under the head of capillary attraction.
IMAGE. The picture of any object which we perceive by reflected light.
IMPENETRABILITY. See page 10.
INCIDENCE. The direction of a body, or ray of light approaching another.
INCLINED PLANE. One of the six mechanical powers.
INERTIA. One of the inherent properties of matter. See page 11.
INHERENT PROPERTIES. Necessary: called also essential properties.
INVISIBLE LADY. See acoustics, page 109.
LATITUDE. Distance from the equator, in a direct line towards either pole.
LATITUDE, PARALLELS OF. Lines drawn upon the globe, parallel to the equator.
LENS. See page 117.

Lever. One of the mechanical powers. See page 38.
Light. That principle, by the aid of which we are able to discern all visible objects.
Longitude. Distance measured in degrees and minutes, either in an eastern, or a western direction, from any given point either on the equator, or on a parallel of latitude.
Luna. Relating to *Luna*, the moon.
Luminous Bodies. Those which emit light from their own substance; as the sun.
Magic Lanthorn, or Lanthorn. An optical instrument. See page 153.
Magnetic Electricity. That science in which magnetic effects are produced by means of electric currents.
Magnetic Poles of the earth; those points of the earth near the north and south poles where the intensity of the magnetic force is greatest.
Magnetism. See *Magnetic Electricity*.
Mathematics. The science of numbers and of extension. Common arithmetic, is a lower branch of the mathematics.
Matter. Substance. Every thing which has length, breadth, and thickness.
Mass. The quantity of matter in a body.
Mechanics. That science which investigates the principles of every machine.
Medium. In optics, is any body which transmits light. Air, water, glass.
Melody. A succession of such single musical sounds, as form a simple air or tune.
Mercury. That planet which is nearest the sun. Quicksilver.
Meridian. Mid-day. A meridian line, is one which extends directly from one pole of the earth to the other; crossing the equator at right angles.
Microscope. See page 147.
Minute. In time, the sixtieth part of an hour. In length, the sixtieth part of a degree.
Mirrors. Polished surfaces of metal, or of glass coated with metal, for the purpose of reflecting the rays of light, and the images of objects. Common looking-glasses, are mirrors. Those used in reflecting telescopes, are made of metal.
Momentum. See page 22.
Motion. See page 20.
Neap Tides. See page 238.
Nodes. Those points in the orbit of the moon, or of a planet, where it crosses the ecliptic or plane of the earth's orbit.
Non Electrics. Substances which cannot be readily excited by friction.
Opaque. Not transparent; refusing a passage to the rays of light.
Optics. That branch of science which treats of light, and vision. See page 109.
Opposition. When two planets are on opposite sides of the sun.
Orbit. The line in which a primary planet moves in its revolution round the sun.
Parabola. A particular kind of curve; that which a body describes in rising and in falling, when thrown upward, in any direction not perpendicular to the horizon.
Parallax. See p. 272.
Parallelogram. A figure with four sides, having those which are opposite, parallel.
Parallel Lines. All lines which are at an equal distance from each other.
Parallel of Latitude. See *Latitude*.
Perihelion. That part of the orbit of a planet, which is nearest the sun.
Pendulum. A body suspended by a rod, or line, so that it may vibrate, or oscillate.
Penumbra. The imperfect darkness which precedes and follows an eclipse.
Perigee. The points in which the sun and moon are nearest the earth.
Perihelion. The point of an orbit nearest the sun.
Percussion. The striking of bodies against each other.
Period. The time required for the revolution of one of the heavenly bodies in its orbit.
Perpendicular. Making an angle of 90 degrees with the horizon.
Phases. The various appearances of the disk, or face of the moon, and of the planets.
Phenomenon. Any natural appearance is properly so called.
Physical. Belonging to material nature.
Physical Sciences. Are included in the term *Natural Philosophy* in its most extended sense, including *Astronomy*, *Heat*, *Electricity*, *Magnetism* &c.
Planet. Those bodies which revolve round the sun, in orbits nearly circular. They are divided into *primary*, and *secondary*; these latter are also called satellites.
Pneumatics. That branch of natural philosophy, which treats of the atmosphere.
Poles. The extremities of the axis of our earth, or of any other revolving sphere.
Power. That force which we apply to any mechanical instrument, to effect motion.
Precession of the Equinoxes. See page 245.
Prism. The instrument usually so called, is employed in optics to decompose the solar ray: it consists of a piece of solid glass, several inches in length, and having three flat sides; the ends are equal in size, and are of course triangular.

PROJECTION. That force by which motion is given to a body, by some power acting upon it, independently of gravity.
PULLEY. One of the six mechanical powers. See page 45.
PUMP. An hydraulic, or pneumatic instrument, for the purpose of raising water, &c.
QUADRANT. A quarter of a circle. An instrument used to measure the elevation of a body in degrees above the horizon.
RADIATION. The passage of light or heat in rays, or straight lines.
RAINBOW. An appearance in the atmosphere, occasioned by the decomposition of solar light, in its refraction, and reflection, in passing through drops of rain.
RAY. A single line of light, emitted in one direction, from any luminous point.
RECEIVER. This name is applied to glass vessels of various kinds, appertaining to the air pump, and from which the air may be exhausted.
REFRACTION. See page 114.
REFRANGIBILITY. Capacity of being refracted. Light is decomposed by the prism, because its component parts are refrangible in different degrees.
REPULSION. A tendency in particles of matter, to recede from each other.
RETINA. The internal surface of the back part of the eye, consisting of the nerve of the eye spread out in a net work, on which images of objects are formed.
SATELLITES. Moons, secondary planets.
SEMI-DIAMETER. Half the diameter. In the earth, it is the distance from its surface, to its centre.
SIDERIAL. Belonging to stars. See Siderial Time, p. 240.
SIGNS, or CONSTELLATIONS. Collections, or groups, of stars. Those of the zodiac are twelve, corresponding with the twelve months in the year.
SKY. That vast expanse, or space, in which the heavenly bodies are situated.
SOLAR. Appertaining to, or governed by, the sun: as the solar system, the solar year.
SOLID. A solid body is one whose particles do not easily move amongst each other, while liquids do.
SONOROUS BODIES. Those bodies which are capable of vibration, so as to emit sounds.
SPECIFIC GRAVITY. The relative weight of bodies compared with a standard, page 63.
SPECTRUM. The rays of light separated into the seven primary colours, and spread out on a surface. See page 141, and the following.
SPHERE. A globe, or ball.
SPHEROID. Spherical; a body approaching nearly to a sphere in its figure.
SPRING TIDES. See page 234, and the following.
STAR. The *fixed* stars are so called, because they retain their relative situations; while the planets, by revolving in their orbits, appear to wander amongst the stars.
SUPERFICIES. The surface of any figure. Space extended in length and width.
TELESCOPE. An instrument by which distant objects may be distinctly seen; the images of objects being brought near to the eye, and greatly magnified.
TEMPERATE ZONES. See page 205.
TORRID ZONE. See page 206.
TRANSIT. Mercury or Venus, are said to transit the sun, when they pass between the earth and that luminary. They then appear like dark spots, upon the face of the sun.
TRANSPARENT. Allowing the rays of light to pass freely through.
TROPICS. See page 205.
VERTICAL. Exactly over our heads: ninety degrees above our horizon.
VIBRATION. The alternate motion of a body, forward and backward; swinging.
UNDULATION. A vibratory, or wave-like motion communicated to fluids. Sound is said to be propagated by the undulatory, or vibratory motion of the air.
WEDGE. One of the mechanical powers. See page 50.
WHEEL AND AXLE. One of the mechanical powers, used under various modifications. Cranes for raising weights, the wheels and pinions of clocks and watches, windlasses, &c. are all applications of this power.
ZODIAC. A broad belt in the heavens, extending nearly eight degrees on each side of the ecliptic; the planes of the orbits of all the planets are included within this space.
ZONE. Divisions of the earth. See *Frigid*, *Temperate*, and *Torrid Zones*, page 205.